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31

TSETSE AND TRYPANOSOMIASIS

comment and article

COMMENT

African Animal Trypanosomiasis

The World Food Conference in 1974 called upon FAO "to launch as a matter of urgency, a long-term programme for the control of African animal trypanosomiasis as a project of high priority". Accordingly, in 1975 FAO initiated the *Programme for the control of African trypanosomiasis and related development* to which very high priority was given. Subsequently, the 10th FAO Regional Conference for Africa held in 1978 confirmed the mandate given by the World Food Conference to FAO.

A five-year preliminary phase of the Programme, in which the necessary technical and administrative structures at international, regional and national levels were to be set up, prior to the development and operation of large-scale projects, is now nearing completion.

The organizational structure worked out will ensure the participation in the Programme of all interested Member Nations and Associate Members of the Organization in Africa, the close association of international organizations and agencies in and concerned with the Programme (especially its financial implications) and adequate technical and administrative support.

Although documents refer to the "FAO Programme", the Programme is, in fact, of and for the African countries and FAO's role is primarily one of coordination in which the Organization will rely heavily on the cooperation and collaboration of OAU, WHO and other organizations.

This means that those African countries wishing to adopt and support the Programme can best do so by initiating discussions with FAO in order to indicate the types of assistance they will be requiring under the Programme.

An indication of the magnitude of the problem of trypanosomiasis in Africa may be gained from the vast area of land, estimated at some 10 million km^2 (a third of the African continent), that is affected. Both humans and animals in this area are affected by this parasitic disease, the causative organism of which, the trypanosome, is transmitted by the tsetse. Of the total area affected some 3 million km^2 is covered by equatorial forest. Much of the remaining area is suitable for either livestock or crop production since it contains some excellent grazing land and large areas of good, virgin agricultural land. This is largely because it has been "protected" by the tsetse from the results of overgrazing and intensive, short-term agricultural exploitation.

Because the need to accelerate pastoral development and to bring more potential farmland into production is becoming increasingly urgent in a number of countries, these are now intensifying their efforts to control the tsetse and trypanosomiasis. The task, however, is so great that coordinated, external technical and financial assistance is essential if these objectives are to be achieved.

While it is hoped that national tsetse and trypanosomiasis control units will be established by those countries that attach importance to the Programme, FAO believes that emphasis has to be placed not only on unilateral tsetse and trypanosomiasis control, but on area development as well. This involves evaluation of agricultural and livestock potentialities and adequate land-use planning of areas to justify the initiation of control measures. Such comprehensive development will help to ensure that the outcome of projects will be successful area and community development rather than the mismanagement of resources freed from tsetse infestation.

Experience in Africa has clearly shown that land use is implicit in the problem of tsetse and trypanosomiasis control and that the costs of the development of land after control has been achieved are likely to be immeasurably greater than the cost of the control of the tsetse itself.

It is most desirable, therefore, that evaluation of the potential resources of an area should precede, or at least accompany, studies of the tsetse that are to form the basis of control plans. Trials to test field control techniques, assessment of stock-carrying capacities, potentialities for water development and irrigation and crop production, etc. have also all to be undertaken before comprehensive or phased area-development can be initiated.

FAO has assured interested governments that it will provide preparatory assistance missions for the purpose of advising them on the formulation of policies, programmes and projects aiming at land resource development parallel with progress made in achieving tsetse control.

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COVER: Highly infected tsetse flies carry the threat of trypanosomiasis over one third of Africa.

Trypanotolerance – a review

M. Murray, W.I. Morrison, P.K. Murray, D.J. Clifford and J.C.M. Trail

It is a well-accepted epidemiological fact that many West African breeds of cattle are able to survive without the aid of chemotherapy in areas of tsetse fly challenge where the humped zebu cannot (Stewart, 1951). In the same way, it is recognized that some breeds of sheep and goats (E.W. Allonby, personal communication), many species of wild life (Ashcroft, Burtt and Fairbairn, 1959) and certain inbred strains of mice (Morrison *et al.*, 1978), also exhibit increased resistance to trypanosomiasis. This phenomenon is known as trypanotolerance although in immunological terms this is a misnomer since trypanotolerant animals do become infected with trypanosomes with adverse effects and they do respond immunologically. Thus, while the term trypanotolerance is now widely accepted, it should be understood to mean no more than reduced susceptibility.

The lack of vaccine and the limitations of the present methods of control, namely chemotherapy and tsetse control, have stimulated the desire to develop additional approaches that might allow more efficient land utilization in the vast areas of Africa dominated by the tsetse fly. Thus, there is now considerable interest in the potential use of trypanotolerant

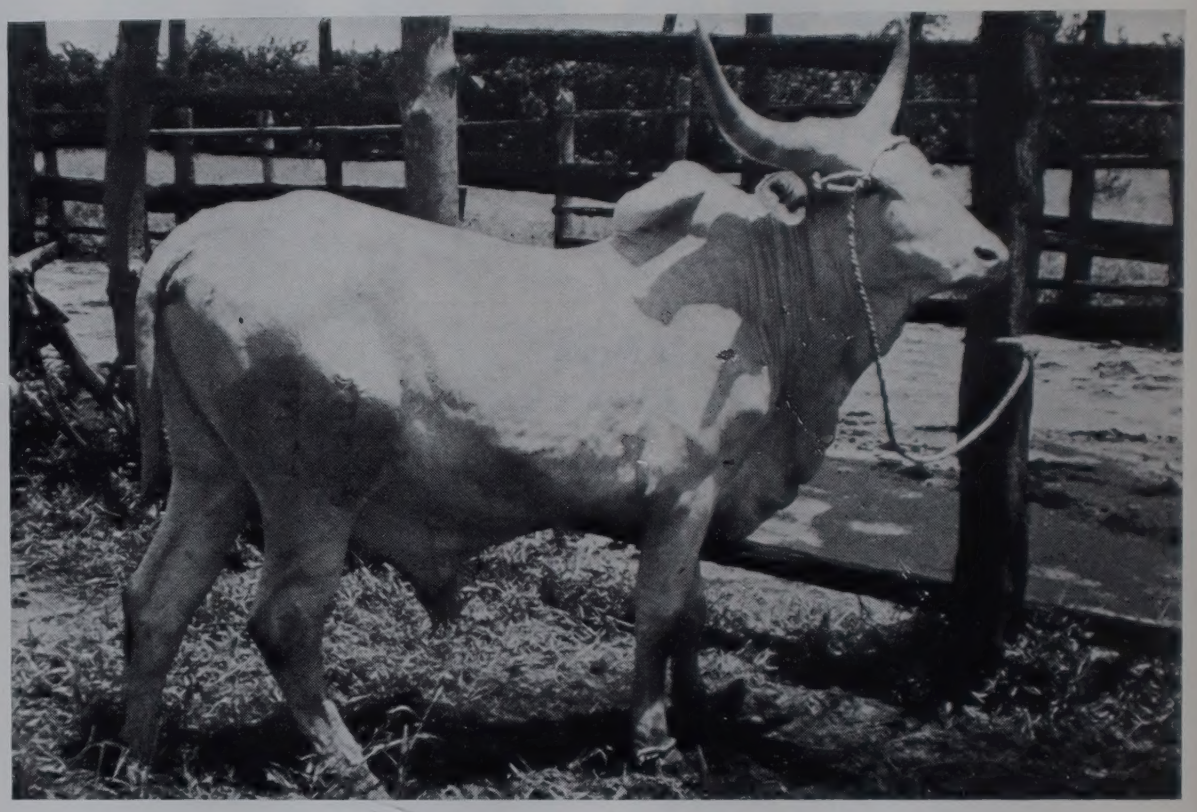

Figure 1. *Zebu. The preinoculation packed red blood cell volume of the zebu in the described experiments was 35 ± 4 (standard deviation)*

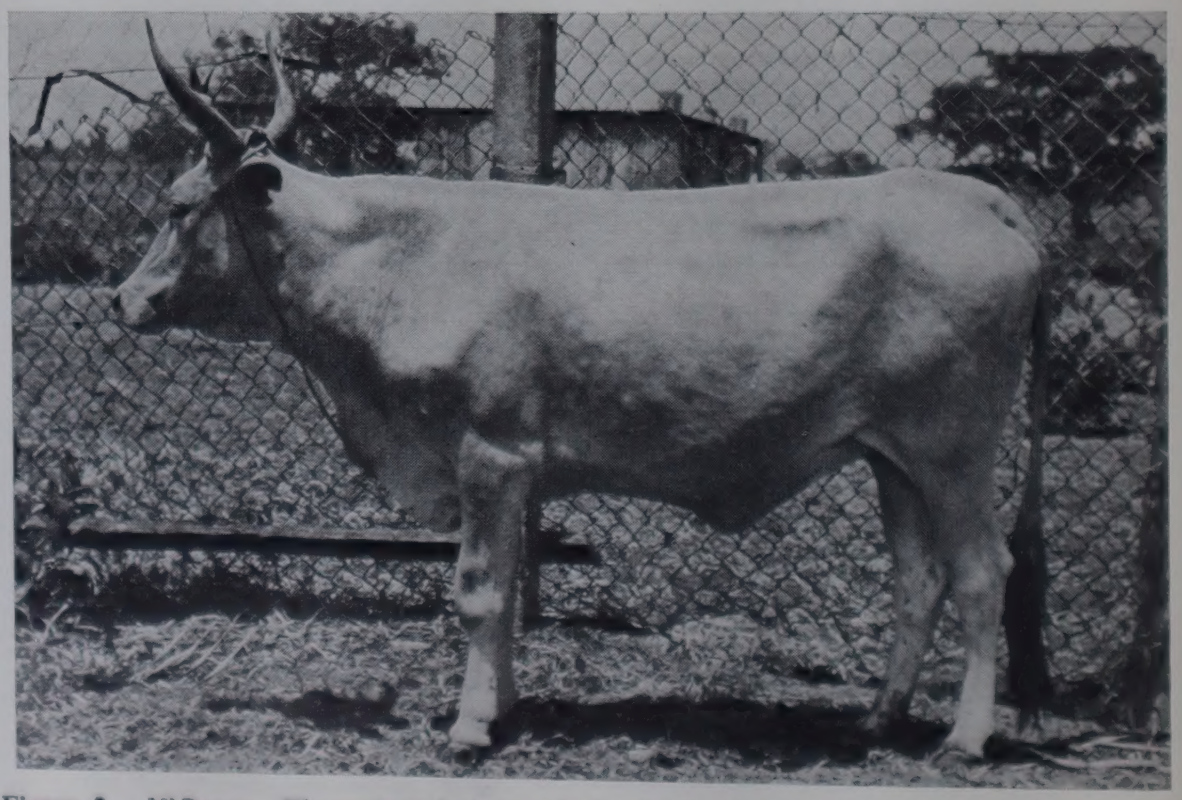

Figure 2. *N'Dama. The preinoculation packed red cell volume of the N'Dama in the described experiments was 35 ± 4 (standard deviation).*

M. Murray and W.I. Morrison are with the International Laboratory for Research on Animal Diseases (ILRAD), PO Box 30709, Nairobi, Kenya; P.K. Murray is with Merck Sharp and Dohme Research Laboratories, Rahway, New Jersey, USA; D.J. Clifford is presently at the Department of Veterinary Services, Abuko, The Gambia (attached to the Glasgow University Veterinary School, Scotland); J.C.M. Trail is at the International Livestock Centre for Africa (ILCA), PO Box 46847, Nairobi, Kenya.

livestock. Particular attention has been focussed on the N'Dama breed of cattle because it has a relatively fixed phenotype and can be improved in productivity. Furthermore, published information has consistently confirmed the greater resistance to trypanosomiasis of the N'Dama over the zebu (Chandler, 1952, 1958; Desowitz, 1959; Stephen, 1966; Roberts and Gray, 1972). However, precise comparative information cannot always be obtained from these publications because in some cases the animals under study had previously been exposed to trypanosomiasis and in others their disease history was not known. In addition group numbers were frequently small, the groups were of widely different ages and of mixed sex. Moreover, many of these investigations were conducted on experimental stations where the general husbandry and feeding were of a high standard; as nutrition has a profound effect on the outcome of the disease (Mortelmans and Kageruka, 1976), it is likely that cattle kept on experimental stations will be more resistant to infection than cattle in natural field conditions.

Thus, most of the basic questions about trypanotolerance remain to be answered precisely, questions such as, to what extent is inheritance important and how is it influenced by environmental factors; what are the mechanisms underlying increased resistance; and how productive are these breeds under various levels of challenge and in different management and ecological situations. The present article attempts to evaluate the current state of knowledge on these questions, leaning heavily on the authors' own experience with cattle and inbred strains of mice.

Trypanotolerance in N'Dama cattle. Over the past few years, a series of experiments on N'Dama and zebu cattle in The Gambia, West Africa, have been carried out. The objectives of this work were, first, to confirm the existence of trypanotolerance in N'Dama and zebu cattle that had no previous experience of trypanosomiasis under different types of challenge, second, to compare the progress of the disease and its immunology in the hope of defining the underlying mechanism of trypanotolerance and, lastly, to evaluate the impact on productivity of different levels of tsetse challenge in N'Dama cattle living under natural field conditions. Preliminary results of these studies have been published by Murray *et al.* (1977 b, c, d and e). A complete report is being prepared by Dr P.K. Murray.

Perhaps the most important aspect of this experimental work is the background of the cattle used. The zebu cattle (Figure 1) were from northern Senegal, purchased from a ranch well beyond the northern limits of the tsetse fly belt. N'Dama cattle (Figure 2) were obtained from the Government Agricultural Experimental Station at Yundum, The Gambia, a location considered tsetse-free, although surrounded by areas infested with

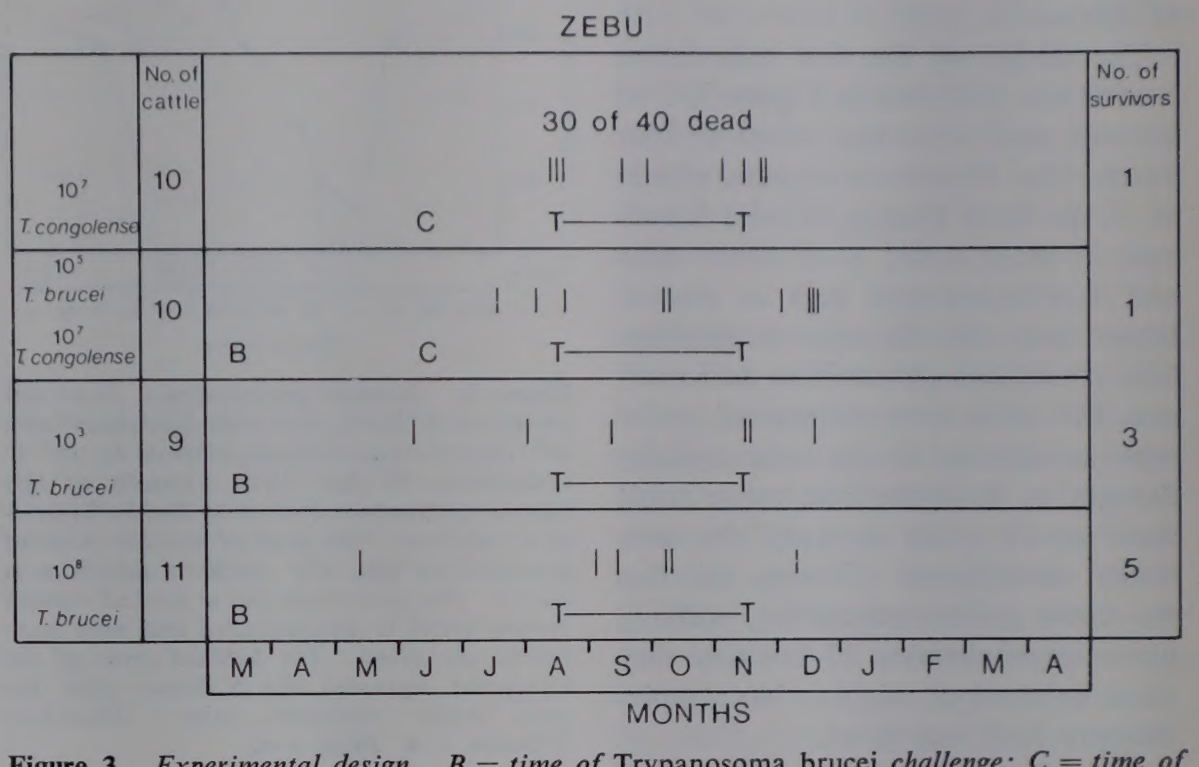

Figure 3. *Experimental design. B = time of* Trypanosoma brucei *challenge; C = time of* T. congolense *challenge;* T—T = *period when the cattle were exposed to* Glossina palpalis.

Figure 4. *Zebu suffering from the effects of inoculation with* Trypanosoma congolense.

Glossina palpalis and *G. morsitans submorsitans*. All animals studied were clinically, parasitologically and serologically negative for trypanosomiasis. There are divisions of opinion on what constitutes an N'Dama and, unfortunately, there is no genetic definition. The N'Dama used in this work conformed closely to the accepted phenotype in this area of West Africa. Furthermore, blood analysis by starch-gel electrophoresis showed a haemoglobin frequency (0.89) similar to that recorded for N'Dama in other parts of Africa.

The design of the first experiment carried out is shown in Figure 3. All animals used were aged three to four years. The 60 zebu were male, whereas of the 61 N'Dama, 34 were female and 27 were male; 8 of these zebu and 9 N'Dama were kept as unchallenged controls. In order to simulate field conditions of nutrition and exercise, the cattle were maintained under such conditions in an area initially thought to be tsetse-free; tsetse traps were set in order to keep the area under surveillance. During the day the cattle grazed extensively, walking up to approximately 27 km and they were tethered at night. No supplementary feed was given.

With the onset of the rainy season in August 1976, the herd came under challenge from *G. palpalis* and this lasted until November. A daily mean of 0.17 flies of both sexes was caught per Malaise trap (W.F. Snow, personal communication). It was estimated that this tsetse challenge commenced 155 days after the needle challenge with *Trypanosoma brucei* and 59 days after inoculation with *T. congolense*. During this time several animals became infected with *T. vivax*.

All 52 inoculated zebu and 52 N'Dama became infected and ill — as judged by deterioration of body condition and the development of anaemia (Figure 4). During the course of the experiment, 12 infected zebu and 15 infected N'Dama were killed for histopathological examination. In the remainder, clear differences in susceptibility emerged between the two breeds. Of the 37 N'Dama allowed to survive, none died, whereas 30 of the 40 zebu died of trypanosomiasis; 9 died after needle challenge (3 infected with *T. congolense*), while the other 21 died during or after the fly challenge. These provided the additional histopathological material.

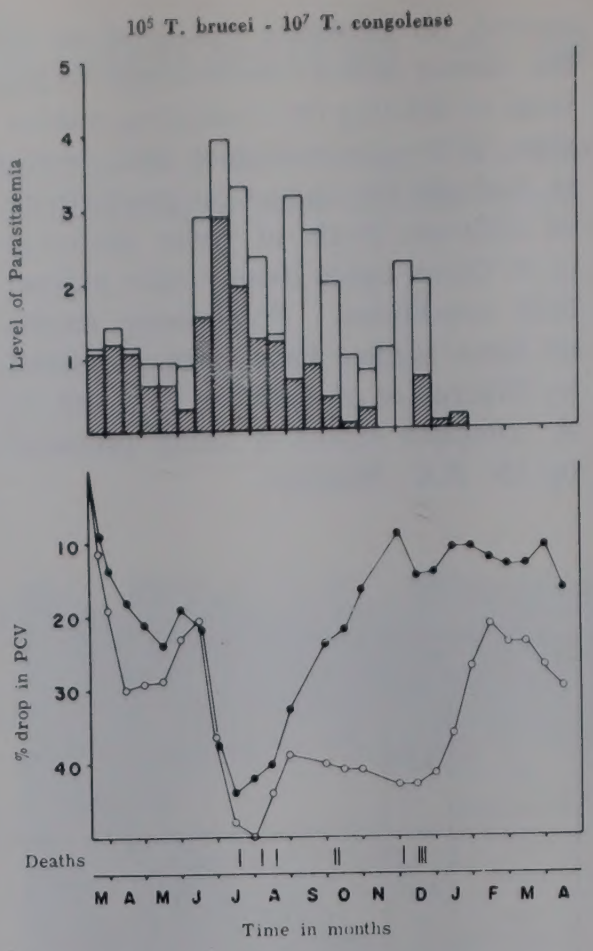

Figure 5. *Average parasitaemia score recorded in N'Dama and zebu inoculated with* 10^5 Trypanosoma brucei *followed by* 10^7 T. congolense *96 days later. Details of this scoring system have been described by Murray* et al. *(1977a). The level of the first peak of parasitaemia plus one standard deviation is shown. The percentage fall in packed red cell volume* (PCV) *is demonstrated and zebu mortalities are given. The hatched areas of the histogram represent the N'Dama while the open areas represent zebu. Elsewhere N'Dama = •; Zebu = o.*

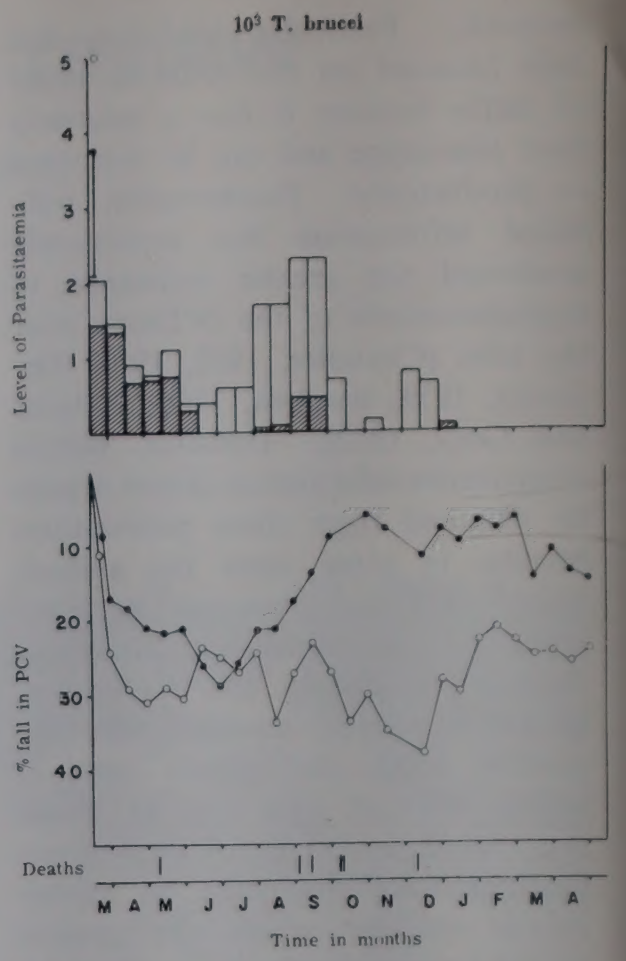

Figure 6. *Average parasitaemia score recorded in N'Dama and zebu inoculated with* 10^8 Trypanosoma brucei. *Percentage fall in packed red cell volume* (PCV) *is demonstrated and zebu mortalities are given. The symbols are as in Figure 5.*

This result was reflected in clear differences in the degree of anaemia that developed in the two breeds. Whereas in both N'Dama and zebu, the onset of the anaemia occurred within a few days of inoculation and was associated with appearance of parasites in the blood, the rate of development and severity of the anaemia was significantly greater in the zebu. This was true for both *T. congolense* and for *T. brucei*, although the severity of the anaemia and the extent of the difference between breeds was much greater in *T. congolense*-infected animals. Nevertheless, it must be pointed out that the isolate of *T. brucei* employed was pathogenic for both N'Dama and zebu and 3 zebu died as a direct result. It was also obvious that N'Dama and zebu previously infected with *T. brucei* were equally susceptible to inoculation with *T. congolense*, although as before the anaemia became more severe in the zebu (Figure 5).

During August when there was some indication that animals were recovering from the needle challenge, as judged by levels of anaemia, *G. palpalis* moved into the area and all zebu infected with *T. brucei* except one were reinfected and severe anaemia developed (Figures 6 and 7); a similar situation occurred with the zebu infected with *T. congolense* (Figures 5 and 8). With N'Dama, however, only a few animals became reinfected and even then only transiently. The tsetse challenge appeared to have little effect on the course of the disease.

On examining the parasitaemia of infected N'Dama and zebu, it was

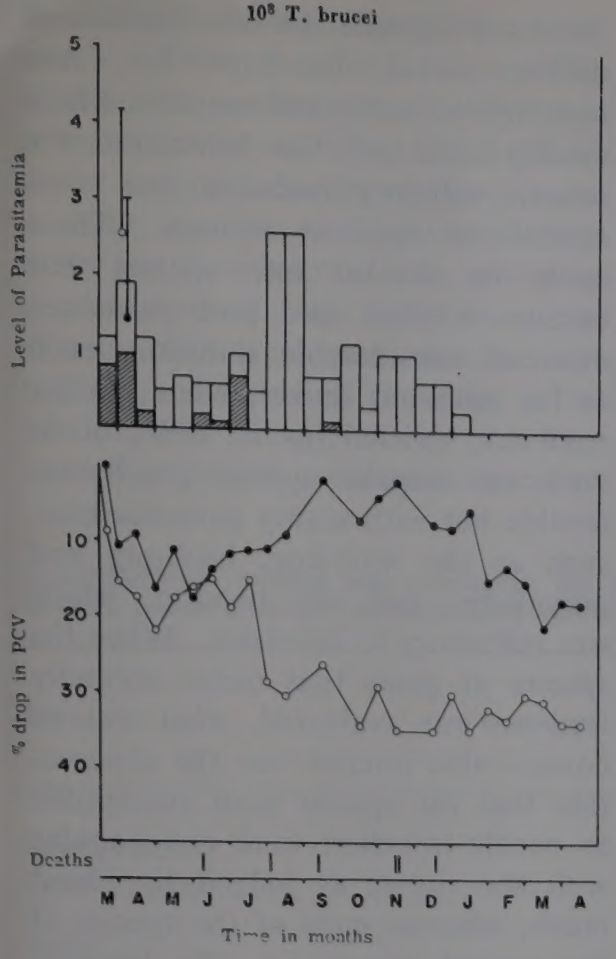

Figure 7. *Average parasitaemia score recorded in N'Dama and zebu inoculated with* 10^3 Trypanosoma brucei. *The level of the first peak of parasitaemia plus one standard deviation is shown. Percentage fall in packed cell volume* (PCV) *is demonstrated and zebu mortalities are given. The symbols are as in Figure 5.*

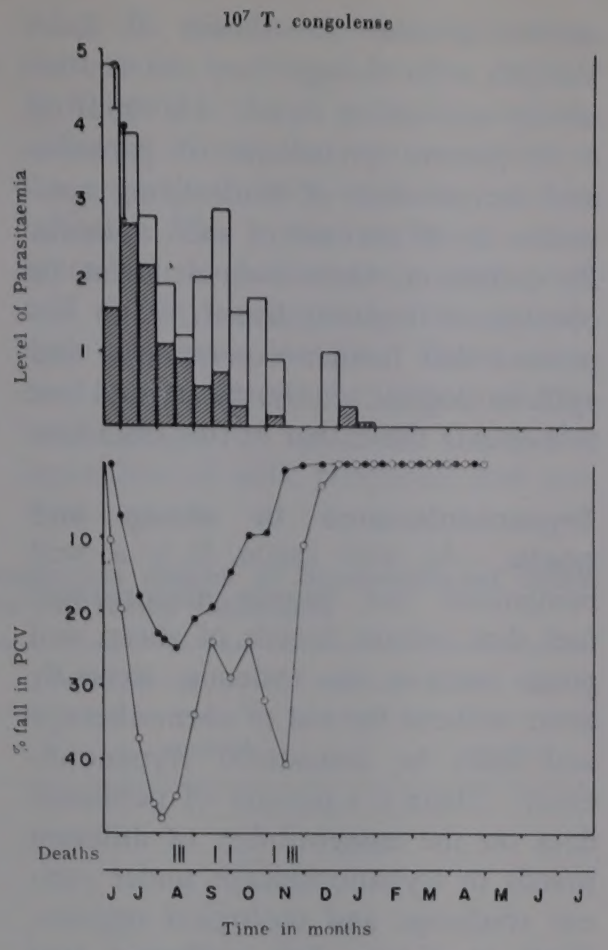

Figure 8. *Average parasitaemia score recorded in N'Dama and zebu inoculated with* 10^7 Trypanosoma congolense. *The level of the first peak of parasitaemia plus one standard deviation is shown. Percentage fall in packed red cell volume* (PCV) *is demonstrated and zebu mortalities are given. The symbols are as in Figure 5.*

immediately obvious that, while the prepatent period was similar, the level of parasitaemia which developed in the N'Dama was consistently and significantly lower than in the zebu. Furthermore, all of the 37 N'Dama allowed to survive and all 10 of the zebu survivors had the apparent ability to eliminate trypanosomes, or "self cure". There was some indication that the duration of parasitaemia was shorter in the N'Dama, but this observation was complicated by the tsetse challenge when most of the zebu, but only a few N'Dama, became reinfected. Nevertheless, from several months after needle challenge onward in most animals and for 90 days prior to termination of the experiment all surviving animals were negative for detectable parasites in the blood and tissues.

Following the disappearance of the parasites from the circulation, 25 of the 37 N'Dama and 3 of the 10 surviving zebu made a slow but complete clinical recovery, as judged by their physical improvement and a return to normal haematological values. However, the remainder did not and, despite the absence of detectable parasites, continued to be anaemic with packed red cell volumes (PCV) approximately 30 to 40 percent below normal. The authors believe this negative anaemic aspect of the trypanosomiasis syndrome to be widespread in the field (Murray, 1979). This outcome should be borne in mind when evaluating Figures 5, 6 and 7, where, by presenting the group mean PCV, a slightly misleading trend is apparent toward the end of the experiment.

Another important finding to emerge from this study was that weight of challenge, as judged by the number of bloodstream forms of *T. brucei* inoculated, had a significant effect on the sequential development of the disease. Both the N'Dama and the zebu that received the heaviest challenge became more rapidly and severely ill and more anaemic than those receiving the lowest dose. The parasitaemic profile was also influenced in that the prepatent period and the level of parasitaemia were lower in the animals inoculated with the lowest dose. In the same way, at least in the N'Dama, it appeared that the dose also affected the period of parasitaemia, the duration being shorter in the group that received the lowest dose; in the zebu, however, this conclusion could not be made because most of them became reinfected during the period of *G. palpalis* challenge. In confirmation of the trypanotolerant nature of the N'Dama breed, but reflecting the quantitative rather than the absolute nature of trypanonotolerance, it was found that the N'Dama receiving the highest challenge, namely, 10^8 *T. brucei*, developed a disease picture of the same order of magnitude as zebu given the lowest dose of 10^3 *T. brucei*. This observation was made only in the initial few months following inoculation and was then complicated by reinfection of the zebu during the period of tsetse fly challenge.

In a further experiment, a group of ten female three-year-old zebu and nine female three-year-old N'Dama were subjected to what was considered a heavy *G. m. submorsitans* challenge. A daily mean of between 20 and 40 flies was caught per Malaise trap (W.F. Snow, personal communication). These cattle had no previous experience of infection. The results were similar to the findings following needle and *G. palpalis* challenge. The zebu developed significantly higher levels of parasitaemia, more severe anaemia and all 10 had died of trypanosomiasis within 242 days of being moved into the challenge area. At this time the average PCV of the N'Dama was still above 30 percent; the only N'Dama death was caused by anthrax.

Based on clinical and post-mortem findings in the above experiments, death from trypanosomiasis was the result of acute congestive heart failure brought about by a combination of

anaemia, circulatory disturbance associated with increased vascular permeability, and myocardial damage. The authors believe that the fact that cattle in this study had to forage for their feed was a contributory factor. Tired, anaemic animals are probably unable to trek the distances necessary to satisfy their nutritional requirements but in their efforts to achieve this they develop cardiac decompensation. It was noticeable that when sick animals were put under intensive care and did not have to forage their clinical condition often improved.

While many aspects of these experiments still await evaluation, what has been established so far is that N'Dama, with no previous experience of infection, were less susceptible than zebu to a variety of challenge situations, including inoculation with *T. brucei* and/or *T. congolense* and to fly challenge with *G. palpalis* and *G. m. submorsitans*; the more virulent the organism the more significant were the differences between the breeds. However, it was found that the trypanotolerant status of the N'Dama was not absolute and was affected by weight of challenge.

Trypanotolerance in other breeds of cattle. There are several other small breeds of cattle in West Africa that are considered to be trypanotolerant (Pagot, 1974). For example, Roberts and Gray (1973) found that Muturu were less susceptible than zebu but more susceptible than N'Dama; however, Desowitz (1959) found that two Muturu from a herd that had not been exposed to trypanosomiasis for 50 years were highly susceptible and succumbed three weeks after infection. However, in an outbred species such as the bovine it is difficult to draw firm conclusions when such small numbers of animals are involved; clearly more experimental data are required for these breeds.

It is generally considered that the zebu is the most susceptible of the African breeds. However, there is considerable epidemiological evidence that, in some areas, zebu have developed a degree of tolerance; for example, Cunningham (1966) has described how thousands of zebu cattle survive around the shores of Lake Victoria even though they are continuously exposed to tsetse. He reported a 30 percent prevalence of parasites and the presence of neutralizing antibodies in 90 percent of such animals. By definition, these animals must be considered trypanotolerant. It is important that further experimental and epidemiological studies be carried out to evaluate the extent of this situation.

Trypanotolerance in sheep and goats. As with cattle, it is a well recognized but poorly documented fact that certain breeds of sheep and goats survive in endemic tsetse-fly areas without the aid of chemotherapy and must be considered trypanotolerant. There is a paucity of published data on the susceptibility of different breeds to trypanosomiasis under various challenge and ecological regimes. Work in Kenya has confirmed that differences in susceptibility do exist between different breeds of sheep and goats to both needle and fly challenge (E.W. Allonby, personal communication); local breeds are much more resistant than imported ones. It is essential that the extent and basis of this difference be further investigated.

Trypanotolerance in wildlife. Wildlife have an established reputation for being trypanotolerant or even completely resistant to trypanosomiasis. There is, however, little published information on infection and the clinical course of the disease in experimentally infected wildlife. Surveys involving the demonstration of the presence or absence of trypanosomes in one blood sample on one occasion yield little useful information on susceptibility to the disease of trypanosomiasis. Sequential studies following experimental infections are required where the clinical, parasitological, immunological and pathological parameters are assessed.

In one of the few studies of this type, Ashcroft, Burtt and Fairbairn (1959) examined the susceptibility of various wildlife species to needle challenge with *T. rhodesiense* and *T. brucei*. They found that the animals examined could be considered to lie in two main categories: first, those species such as Thomson's gazelle, dik-dik, Blue Forest duiker, jackal, bat-eared fox, Ant bear, hyrax, serval and monkey, which usually died of the infection: the second category included less susceptible or resistant animals. These could be divided into species that became infected and had parasitaemias of considerable duration, such as the common duiker, eland, Bohar reedbuck, spotted hyena, oribi, bushbuck and impala; species usually infectible but with scanty parasitaemias, such as the wart-hog, bush-pig and porcupine; and the baboon, which was refractory to infection. When the species of game that tsetse normally feed on was evaluated, what was of considerable interest was the observation that the species most susceptible to needle infection were not popular with the tsetse, as judged by blood meals, whereas most of the species of the second group, i.e., the less-susceptible group, were fed on more regularly, with wild pigs being most popular. This observation would suggest that species in the second group may have evolved by the survival and selection of the more resistant members within each of these species. In a similar but more limited study, Carmichael (1934) also found a range of susceptibility to *T. brucei* between different species of wildlife. Both Carmichael (1934) and Ashcroft, Burtt and Fairbairn (1959) attempted to infect a small number of game animals with *T. congolense*. They found that in most cases the animals tested were not infectible or developed only transient infections and then recovered.

It would appear essential to the authors that such studies be extended. Not only is it important to evaluate the epidemiological role of game animals in African trypanosomiasis but also the fact that certain species are less susceptible or even refractile to trypanosome infection makes them important subjects for studies into the basic mechanisms of trypanotolerance. It may be, for example, that the resistant wildlife host can "see" antigens in the trypanosome that make the trypanosome more vulnerable; alternatively, these species may have certain blood proteins that are active in a non-specific way against the trypanosome.

Productivity of trypanotolerant livestock. There is a lack of scientific data on the productivity of "trypanotolerant" livestock living in the field under natural tsetse-fly challenge. As a result, a variety of opinions exists as to just how tolerant and how productive these animals really are under various ecological and management regimes and levels of challenge. The productivity of trypanotolerant livestock is especially called into question on the basis of their small size in comparison with more susceptible breeds. At one extreme is the view that N'Dama cattle are genetically resistant and do not suffer from trypanosomiasis and should be introduced widely into high tsetse-fly challenge areas throughout Africa (Pagot, 1974). Other workers feel that further information is necessary before taking such an ambitious step (Stewart, 1951; Chandler, 1952; Roberts and Gray, 1973). At the other end of the scale, Stephen (1966) concluded that the propagation of these breeds, because of their small size, is not to be recommended as a satisfactory means of protein production.

In a recent major survey of the status of the trypanotolerant livestock of West and Central Africa (ILCA, 1979), indices of productivity of trypanotolerant cattle were examined, using all the basic production data that could be found in the region. In 30 herds in the 18 countries studied, sufficient information was available on the main production traits to produce indices. The traits evaluated were reproductive performance, cow and calf viability, milk production, growth and cow body weight. These were used to compute the index of the total weight of calf and liveweight equivalent of milk produced, first per cow per year and finally per 100 kg of cow maintained per year. This final index related these important production traits back to the actual weight of breeding cow that had to be supported, this being closely connected with maintenance costs. The traits and production indices were derived for two basic management systems, village and ranch or station and for four levels of tsetse challenge rather arbitrarily designated zero, low, medium and high. The table indicates the effects of breed groups, management system and tsetse challenge on the two productivity indices.

Least-squares' means and constants for production indices of trypanotolerant cattle breeds under different management systems and tsetse challenges

Item	Number	Index/cow (kg)		Index/100 kg cow (kg)	
		$\bar{x}$	constant	$\bar{x}$	constant
Overall mean		57.5		28.0	
Total number	30				
Breed					
N'Dama	21	71.3	13.8	28.4	0.4
West African Shorthorn	9	43.7	—13.8	27.6	—0.4
System					
Ranch/Station	16	70.9	13.4	33.1	5.1
Village	14	44.1	—13.4	22.9	—5.1
Tsetse challenge					
Zero	3	89.2	31.7	40.0	12.0
Low	13	66.3	8.8	31.0	3.0
Medium	10	45.9	—11.6	22.7	—5.2
High	4	28.6	—28.9	18.2	—9.8

A tremendous range of productivity levels was spanned by both the N'Dama and West African Shorthorn relative to the different production systems and level of tsetse challenge involved. In both breeds, the range extended from about 15 kg of one-year-old calf and liveweight equivalent of milk produced per 100 kg of cow maintained per year under village conditions in a high tsetse-challenge area, to about 50 kg under improved ranch or station conditions in a low tsetse-challenge area.

The table indicates no significant difference between N'Dama and West African Shorthorn for the major index of "productivity per 100 kg of cow maintained", the actual values being 28.4 kg per annum for N'Dama and 27.6 kg for West African Shorthorn. The only significant differences in individual traits leading to this index were of one-year-old calf and weight of mature cow, the N'Dama group being very much heavier in each case. The higher calf weight led to a higher index per cow for the N'Dama, but the higher mature-cow weight resulted in similar indices per 100 kg of cow maintained. The effect of management system was a 38 percent lower productivity index per cow and 30 percent lower productivity index per 100 kg of cow maintained from the village compared with the ranch or station. The performance attributable to zero tsetse challenge was masked by the effect of very intensive feeding and management, thus only low, medium and high can be directly compared. Productivity indices per cow were 30 percent and 56 percent less for medium and high challenge respectively compared with low, while indices per 100 kg of cow maintained were 26 percent and 41 percent less for medium and high respectively compared with low.

Estimates of productivity for 16 zebu and Sanga herds under ranch/station conditions in tsetse-free areas of Africa covering Botswana, Kenya, Mali, Nigeria, Senegal and Uganda, have been built up from the available literature. These averaged 133.4 kg of one-year-old calf and liveweight equivalent of milk produced per cow maintained per year and 37.7 kg per 100 kg of cow maintained per year. Compared with the estimates of 79.7 kg and 36.1 kg for the 30 trypanotolerant groups under ranch/station conditions in light tsetse-challenge areas, these represent a superiority of 67 percent per cow. maintained per annum, but only 4 percent per 100 kg of cow maintained

per annum for the zebu and Sanga over the trypanotolerant breeds. This strongly suggests that the productivity of trypanotolerant cattle relative to other indigenous types may be much higher than previously assumed.

A preliminary survey of the impact of trypanosomiasis has been carried out on the N'Dama on The Gambia[1], which live under different levels of tsetse challenge (Murray *et al.*, 1977b; Clifford and McIntyre, 1977). It was found that in heavy *G. m. submorsitans* areas anaemia was widespread and up to 50 percent of the herd could be infected. In areas of lighter *G. palpalis* challenge, the prevalence of trypanosomes was less as was the extent of anaemia. In the heavy challenge areas, while some of the trypanosome-infected N'Dama died, most N'Dama survived but they often did so in a poor productive state with wasting, stunting (Figure 9), abortion, high calf mortality and with a persistent low-grade anaemia being manifest. Thus, there is little doubt that trypanosomiasis must be considered a disease of importance in N'Dama in terms of morbidity if not mortality. However, it should be emphasized that many other animals in the same herds were in an excellent productive state, suggesting that a wide range of susceptibility exists within the N'Dama breed. It must be remembered that these results were obtained in areas where zebu could not survive; of 31 zebu introduced in the *G. m. submorsitans* area in June 1977, only one survived until December 1978, and this animal was in poor condition. In the same way, of the 31 zebu studied in the *G. palpalis* area 21 died; the N'Dama in this area were hardly affected.

These N'Dama herds, numbering around 2 000 head, are now double ear-tagged and have been investigated from a disease and productivity point of view over several years. Detailed quantitative data are at present being evaluated by one of the authors (D.J. Clifford).

[1] Not all of these herds are pure N'Dama and some are judged to have a component of West African Shorthorn.

Basic mechanisms of trypanotolerance. While the basic mechanism of trypanotolerance is still to be precisely defined, there is at least circumstantial evidence that the mechanism is related to a host-response factor and that it is a heritable trait.

The trypanotolerant nature of the N'Dama and the capacity of certain strains of mice to survive a trypanosome infection longer than others (Morrison *et al.*, 1978b) would appear to be related to their ability to limit the level of peaks of parasitaemia and subsequently to control, reduce or even eliminate the parasite. The finding of a similar prepatent period between N'Dama and zebu, and between strains of mice of high and low susceptibility suggested that the initial replication rates in all groups were similar. Furthermore, dose titration studies showed that there was no difference in the infectivity of *T. congolense* for mice of high and low susceptibility (Morrison *et al.*, 1978b). These findings indicated that the different levels of parasitaemia found between breeds of cattle and strains of mice might reflect differences in the nature or quality of the immune response to the trypanosome. This hypothesis requires experimental verification.

Evidence that a more effective immune response might be responsible for the differences in susceptibility between N'Dama and zebu cattle comes from the work of Desowitz (1959). He found that N'Dama with previous experience of trypanosomiasis were able to eliminate trypanosomes more rapidly than their zebu counterparts following a renewed challenge. Employing an *in vitro* test that involved the use of sera from the challenged animals to inhibit trypanosome respiration, it was found that the activity of N'Dama sera was superior to that of zebu sera. Desowitz (1959) concluded that the trypanotolerant nature of the N'Dama lay in its capacity to mount a better secondary immune response. Unfortunately, in these studies the trypanosomal antigenic history of the N'Dama and zebu used was not known precisely. Thus, while the results achieved are indicative of a more-effective immune response in the N'Dama they require confirmation. Similarly, using a serum neutralization test, Chandler (1958) stated, without supplying details, that the immune response of zebu to the trypanosome was inferior to that of the N'Dama.

A range of susceptibility to *T. congolense* (Morrison *et al.*, 1978) and to *T. brucei* and *T. vivax* (Morrison and Murray, 1979) has been shown to occur in different inbred strains of mice. Following *T. congolense* infection, the *C57Bl* was the least susceptible and the *A/J* was the most susceptible of the strains examined. When the spleen lymphocyte populations were studied in these strains of mice infected with *T. congolense*, it was found that there was a marked increase in splenic B-lymphocytes and null cells (Morrison *et al.*, 1978). This, allied to the findings of an increase in background plaque-forming cells to sheep erythrocytes, indicated that trypanosome infection resulted in a nonspecific polyclonal activation of lymphocytes, affecting primarily B-lymphocytes. In the strains of mice that survived longest, the *C57Bl* and *AKR*, the increase in B-cells and null cells was less than in the highly susceptible strains. Furthermore, the immunosuppression observed in mice infected with *T. congolense* occurs earlier in the highly susceptible strains. It might be, therefore, that susceptibility is related to sensitivity to polyclonal activation or to immunosuppression induced by the trypanosome infection. Alternatively, differences in the cellular response and degree of immunosuppression might merely reflect differences in levels of parasitaemia observed in the various strains of mice (Morrison *et al.*, 1978).

Further support for the hypothesis that trypanotolerance has an immunological basis comes from the effect of immunostimulants on the susceptibility of mice to trypanosomiasis (Morrison and Murray, 1979). The authors found that the administration of *Bordetella pertussis*, *Corynebacterium parvum* or Bacillus Calmette-Guérin (BCG) prior to or on the day of challenge with *T. congolense* significantly delayed or reduced parasitaemias and increased survival time. In this way, it was pos-

sible to change the survival time and parasitaemia levels of the highly susceptible *A/J* strain to values more akin to the less susceptible *C57Bl*. This strategy might have practical significance in rearing domestic livestock.

Further work is now required to define both qualitatively and quantitatively the host's immune response to the trypanosome and to compare this between breeds and strains of animals with different susceptibilities. In this way the important effector mechanisms might be clearly defined and, moreover, it might be possible to potentiate them with the object of increasing host resistance to trypanosomiasis.

It is also essential that possible physiological factors be considered in the construction of the overall picture of the underlying mechanisms of trypanotolerance. As the N'Dama tend to develop less-severe anaemia than zebu, the authors considered that this might be related to the capacity to mount a more effective erythropoietic response. Thus, a series of *in vivo* pathological studies were carried out in N'Dama and zebu cattle infected with *T. congolense* and *T. brucei*; these studies involved the use of ^{51}Cr-labelled red cells, ^{125}I-labelled albumin and ^{59}Fe-labelled transferrin (Dargie *et al.*, 1979; Dargie *et al.*, 1979). The findings, however, showed that the anaemia and its underlying processes were broadly related to the number of parasites in the blood and that the superior resistance of the N'Dama lay in their capacity to control parasitaemia rather than their ability to mount a more efficient erythropoietic response.

Nevertheless, it would seem to us that, when N'Dama and zebu are kept under the same conditions and have anaemia of similar severity, the N'Dama always appear to be clinically and physically superior.

Figure 9. *The effect of trypanosomiasis on a naturally-infected N'Dama yearling. The animal is stunted and has a characteristic "nagana" pose.*

Under normal field conditions where nutrition is poor, cattle often have to forage up to about 27 km in a day; perhaps the N'Dama's ability to forage and to digest what it gets is superior to the zebu. Several other physiological mechanisms are also worthy of consideration. The authors have observed remarkable water conservation and heat tolerance in N'Dama; rectal temperatures can range from 34.4°C at dawn to 41.1°C by late afternoon. Furthermore, Pagot (1974) has pointed out that N'Dama can withstand higher levels of humidity than zebu. Zebu appear to have evolved a capacity for conserving water and in East Africa it has been shown that the water requirements of zebu steers is half that of Hereford steers and is as specialized as several species of game animals (EAVRO, 1967). Zebu were found to be better able to conserve evaporative and faecal water than Hereford. Zebu deprived of water stopped eating and metabolised fat consequently reducing urinary and faecal water losses; zebu cattle form faeces as dry as 190 g water/100 g dry matter whereas Hereford are unable to form faeces containing less than 300 g water/100 g dry matter. As a, result, zebu were able to live comfortably without water for two months at an environmental temperature of 22°C or until their fat supplies were depleted, a fact confirmed by field observations on Turkana cattle living under drought conditions. This capacity for conserving water was inherited as a dominant trait in zebu-Hereford F_1 crosses (EAVRO, 1967). In possible contrast to N'Dama, zebu would appear to regulate their body temperature within a range of 2°C and neither a periodic heat load nor dehydration had any effect on the range over which zebu regulate (EAVRO, 1967). The greater variation in body temperature in the N'Dama compared with zebu might result in better conservation by N'Dama of water which would otherwise be lost by evaporation. The authors believe that these observations require further investigations to evaluate the possible role played by adaptation of physiological mechanisms in trypanotolerance.

Another aspect that might play a potential role in trypanotolerance is skin physiology, including colour and smell, in relation to attractiveness to the tsetse; skin structure might also be important. In addition the role of nonspecific factors in host susceptibility to trypanosomiasis should be compared between breeds; these factors might include the extent and activity of the mononuclear phagocytic system as well as complement, properdin and conglutinin reactivity. One

interesting finding is that the N'Dama breed has a significantly higher level of white blood cells, particularly eosinophils, than the zebu. This observation was made by Oduye and Okunaiya (1971) and the authors subsequently have confirmed their findings.

The genetics of trypanotolerance. There is now a considerable body of evidence to show that trypanotolerance has a genetic basis. Thus, studies on cattle that have had no previous experience of trypanosomiasis have clearly established that N'Dama are significantly more resistant than zebu (Stephen, 1966; Roberts and Gray, 1973). It is likely that trypanotolerance has evolved in tsetse-fly infested areas by natural selection of the more resistant animals within a breed. In this respect (in the authors' experience) a range of susceptibility is found both within groups of N'Dama and zebu cattle. Under such circumstances it is likely that the factors governing the susceptibility have a complex genetic basis.

There have been few breeding studies with trypanotolerant breeds of cattle. Stewart (1951) reported crossbreeding studies, without supplying details, involving the West African Shorthorn, a trypanotolerant genetic mix, and zebu, in which trypanosomiasis resistance was retained in the crossbred offspring. However, Chandler (1958) found that the resistance of N'Dama-zebu crosses to trypanosome challenge was about half way between the two parent breeds. In an extended crossbreeding trial in the Ivory Coast involving large numbers of N'Dama and Jersey, it was found that the F_1 cross produced an excellent animal as regards growth and milk production (Letenneur, 1978). It was stated that such crosses retained their tolerance although no data were supplied on the level of fly challenge or on the prevalence of trypanosomes. Crossbreds with greater than 50 percent Jersey background appeared to be less hardy and gave equivocal results. The foregoing reports indicate that the trypanotolerant trait is at least partly dominant. However, in using such outbred populations, differences in results on crossbreeding must be expected. Indeed, it is likely that the degree of trypanotolerance observed in first generation crosses will vary widely depending on the individual parental combination. In this respect, any future investigation of the inheritance of trypanotolerance will require the use of large groups of both parental breeds if reliable results are to be obtained. Thus, only by using sufficient numbers of animals will it be possible to determine the feasibility of selection for maximum trypanotolerance along with the retention of the required characteristics of the non-trypanotolerant parent. The main problem in undertaking such a study at present is the lack of genetic markers that would allow monitoring of susceptibility without having to infect all of the animals involved.

It has been proposed that, as N'Dama cattle show almost 100 percent gene frequency for Haemoglobin (*Hb*) *A*, while zebu are a mixture of *A* and *B*, animals could be selected by *Hb* type. However, the fact that certain exotic breeds such as the Friesian are predominantly *HbA* (Bangham and Blumberg, 1958) and are highly susceptible to trypanosomiasis, makes it unlikely that *Hb* type will be of value as a marker. With the recent upsurge of interest in the major histocompatibility complex (MHC) in cattle and the identification of a series of gene products, the possible association of trypanotolerance with particular MHC products might prove a more profitable avenue of research.

The lack of suitable herds for study, the absence of genetic markers for resistance and the genetic heterogeneity of bovine populations, at present preclude a critical analysis of the genetics of trypanotolerance in the bovine. Thus, the authors have carried out a series of experiments to compare the susceptibility of different inbred strains of mice to trypanosomiasis and to investigate the underlying genetics (Morrison *et al.*, 1978; Morrison and Murray, 1979).

As stated earlier, it was found that strains of mice differed markedly in their susceptibility to African trypanosomiasis. Breeding studies indicated that reduced susceptibility (as judged by survival times) was inherited as a dominant trait, in that F_1 hybrids between the highly susceptible *A/J* strain and the more-resistant *C57Bl/6* showed similar survival times to the *C57Bl/6* parents (Figure 10). When these F_1 hybrids were then back-crossed onto the parent strains, the extent of heterogeneity in survival indicated that susceptibility was under polygenic control (Morrison and Murray, 1979).

In recent years, the susceptibility to a number of experimental infections in mice and the prevalence of certain diseases in man has been shown to be at least partially linked to *H-2* haplotype (Lilly and Pincus, 1973; Mc Devitt, Oldstone and Pincus, 1974) and with particular *HLA* antigens (Vladutiu and Rose, 1974) respectively. It has been suggested that *H-2* may exert its influence through immune response (*Ir*) genes present in the *I* region of the *H-2* complex. It is thought that immune response genes may also be associated with the *HLA* complex in man. However, the authors' studies on the comparative susceptibility of congenic resistant mice, i.e., mice with a genetic background differing only at the *H-2* locus, have failed to demonstrate a major relationship between *H-2* haplotypes and susceptibility (Morrison and Murray, 1979). So far, the authors have carried out these experiments only on mice of the *C57Bl* genetic background and it may be that the genes responsible for reduced susceptibility in this strain override any influence exerted by the *H-2* haplotype.

Despite the lack of precise data there would appear to be overwhelming evidence that susceptibility of cattle to African trypanosomiasis is under genetic control. Nevertheless, there is a considerable body of evidence to support the fact that the innate susceptibility of cattle is decreased by repeated exposure to the same population of trypanosomes in a given area. Thus Desowitz (1959) demonstrated the ability of N'Dama and, to a lesser extent, zebu that had been previously exposed, to mount what could be described as a secondary immune response with the elimination of the parasite. He believed that the course of the disease was dependent not only on the breed of animal but

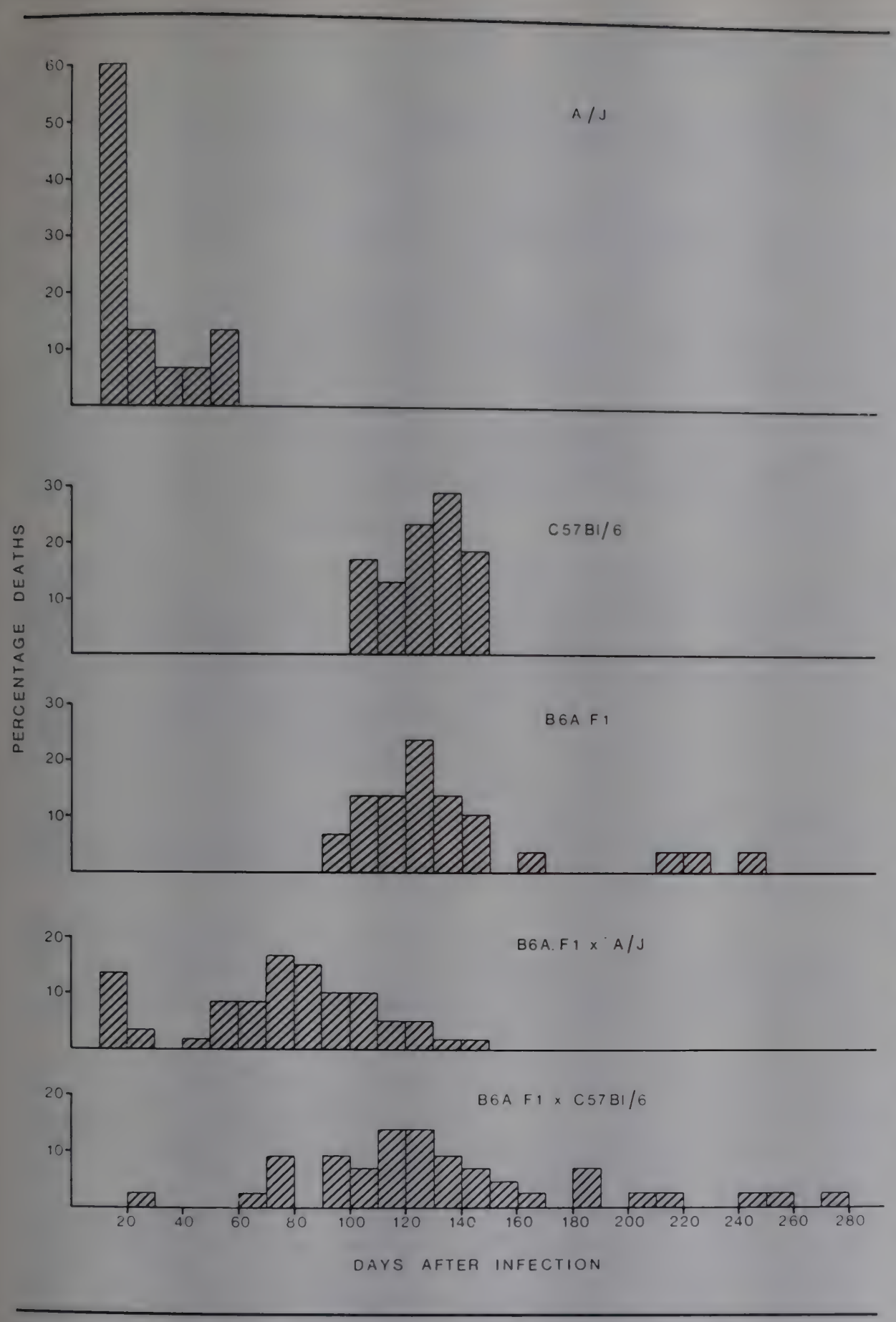

Figure 10. *Percentage deaths in groups of* A/J, C57Bl/6J, F_1 *hybrids and backcrosses after infection with* Trypanosoma congolense. MORRISON AND MURRAY, 1979

also on the nature of the individual's past contact with the trypanosome. The fact that cattle previously exposed to trypanosomiasis are more resistant was described many years ago by Bevan (1928) and more recently by Wilson *et al.* (1976) who showed that zebu cattle kept under an infection-and-treatment regime did become more resistant.

In addition to previous exposure to infection, it is established that other factors, such as weight of challenge, influence susceptibility. Studies have shown that if the dose of inoculum is heavy enough N'Dama can become very ill and may even die (Murray *et al.*, 1977 a, e).

In addition, it is essential that the effect on susceptibility of such factors as nutrition, stress, exercise, age of first exposure, effect of colostrum, sex, pregnancy and parturition be fully investigated. The effect of intercurrent disease must also be considered as must the relative susceptibility of trypanotolerant breeds to other infections; it has been reported, for example, that N'Dama are more resistant to streptothricosis (Oduye and Okunaiya, 1971). In addition, the impact of transferring trypanotolerant stock to a distant location must be critically evaluated in order that the conflicting opinions that exist on movement may be resolved; this is obviously one of the most important questions to be answered about trypanotolerance although the successful establishment of trypanotolerant breeds in Zaire and elsewhere would suggest that these breeds do adapt (Pagot, 1974; Mortelmans and Kageruka, 1976).

Conclusions. There is now a considerable body of evidence, both epidemiological and experimental, to confirm the existence of trypanotolerance. It would also appear that trypanotolerance has a genetic basis although this may be supplemented by repeated exposure to the same population of trypanosomes in a given area. However, trypanotolerance is not absolute and breaks down if the weight of challenge is heavy enough. Further work on the genetics of susceptibility in cattle, sheep and goats and precise information on the effect of environmental factors are necessary.

The productivity of trypanotolerant livestock relative to other indigenous types may be much higher than previously assumed; they could well be an economically viable proposition in their own right and be introduced into areas where other livestock cannot exist. Furthermore, it is likely that strategies involving immunotherapy, if and when available, and drugs will be more effective and economically viable if carried out on trypanotolerant stock. Finally, there is little doubt that comparative studies of trypanotolerant and susceptible animals offer one of the best approaches for the understanding of the important immunological mechanisms and physiological factors involved in host-parasite interactions operative in African trypanosomiasis. ■

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The value of Leucaena leucocephala as a feed for ruminants in the tropics

R.J. Jones

Animal production in many parts of the tropics and subtropics is limited by a deficiency of protein. This deficiency is particularly marked in areas with a long dry season when greed feed is limited or absent. The use of legumes to contribute nitrogen to the system and to provide high-protein feed into the dry season has resulted in some dramatic increases in animal production in the tropics (Stobbs, 1975), which have encouraged the more widespread adoption of this technology.

A number of legumes are now available for use in tropical and subtropical areas (Hutton, 1970, 1974) and of these Leucaena leucocephala (*leucaena*) *has recently been given prominence in a National Academy of Sciences publication (NAS, 1977). In addition to its use as a forage plant, which is, as yet, not widespread, leucaena has many other uses of interest in the tropical and subtropical world.*

This article concentrates on the value of leucaena as an animal feed and, in particular, as a feed with the potential to increase ruminant animal production.

Agronomic characteristics. Unlike most other legumes recommended for pastures in the tropics, leucaena (*Leucaena leucocephala*) is a shrub or tree. It grows well in a wide range of soils with the marked exception of very acid soils (with low base status) and waterlogged soils, and is particularly well adapted to calcareous clay soils. These characteristics have been well documented in the reviews of Oakes (1968), Gray (1968) and Hill (1971). They are only briefly discussed here.

The species *L. leueocephala* is represented by a number of plant forms. The most widespread in many tropical areas is a shrubby free-seeding form known as "Hawaiian" leucaena, which tends to be weedy and low yielding. More-productive, multibranched, semi-erect, medium-height forms and forms that flower later than the Hawaiian are represented by the cultivars Peru and Cunningham. The tall, erect, sparsely branched forms, which may also be grown as forest trees, are represented by the "giant" cultivars K8 and K28. All are palatable to livestock and regrow rapidly after cutting or grazing.

The species will grow anywhere in the tropics and subtropics within an annual rainfall range of 500 to 3 000 mm. Its *Rhizobium* requirements are highly specific and all seed must be inoculated. While able to grow in frosty conditions its yield is greatly reduced at low temperatures, at high altitudes and in dry conditions. In the wet tropics, yields of 20 t dry matter/ha/year have been obtained with crude protein yields in excess of 3 t/ha. These are much higher than for most other tropical legumes and are equivalent to nitrogen fixation rates of up to 500 kg N/ha/year. At the other end of the scale, yields of 5 t/ha/year can be expected under cooler or drier conditions.

Nutritive value of leucaena for ruminants. Although a shrub, leucaena is very palatable to livestock. Regrowing shoots, 0.5 to 1 m long, are usually composed of 75 to 80 percent of highly nutritious leaf. The young green stems up to 5-6 mm diameter are also eaten. Thickened stem is far less palatable and nutritious than the leaf or young stems as is shown in Table 1.

The leaves, young stems, flowers and pods are all excellent sources of protein and minerals. One notable exception is sodium, which is low in all plant parts. Another is iodine, which has been found to be low in leucaena, varying from 33 to 90 micrograms per kilogram, and this compares with a requirement by ruminants of approximately 800 micrograms per kilogram (0.8 ppm) (Agricultural Research Council, 1965).

Leaf material of leucaena compares favourably with alfalfa or lucerne (*Medicago sativa*) leaf material in terms of protein and minerals as shown in Table 2, which also shows that the amino-acid composition of these two species is very similar except for the

Dr Jones is Officer-in-Charge at the CSIRO Division of Tropical Crops and Pastures, Davies Laboratory, Private Mail Bag, Post Office, Townsville, Qld. 4810, Australia.

higher isoleucine content of the leucaena. The presence of significant amounts of tannins in leucaena may also have important nutritional implications as far as the ruminant is concerned since, unlike lucerne, no cases of bloat have been noted in cattle grazing on leucaena. These tannins may also have an important role in the protection of protein from degradation in the rumen and therefore in making it more available in the small intestine.

The calcium concentration in leucaena appears to vary considerably, depending on the location. For example, under Australian conditions, on a variety of soils, the calcium concentration rarely exceeds 1 percent in the dry matter whereas in the material grown in India and Malawi, values of more than 2 percent calcium are reported in leucaena leaf.

Leucaena leaf material is also an excellent source of β-carotene, which could be a valuable characteristic, particularly during the dry season when leucaena is able to retain green leaf better than many other pasture species.

There are very few reports on the digestibility of leucaena when fed to ruminants. Values of 50 to 71 percent dry-matter digestibility are reported in the literature (Singh and Mudgal, 1967; Joshi and Upadhyaya, 1976; Upadhyay, Rekib and Pathak, 1974). The lower digestibility values were obtained when leucaena was fed in a mixture and the digestibility calculated by difference and the higher value of 71 percent was calculated using goats on a pure feed (see Table 3). The value of 71 percent accords with values for the digestibility of leaves and young shoots of leucaena fed as a pure diet to cattle and goats (R.J, Jones, unpublished data).

In spite of the high digestibility and excellent chemical composition of these diets, voluntary feed intake ranges from 1.7 to 2.7 percent of body weight or 58 to 85 g/kg liveweight 0.75 (Upadhyay, Rekib and Pathak, 1974; Jones, Blunt and Nurnberg, 1978). The limited amount of data available suggests that animals fed a pure diet of leucaena do not make sustained gains in weight. Such animals either maintain weight, lose weight throughout the experimental period or gain weight acceptably to begin with and lose weight subsequently (Compere, 1959; Singh and Mudgal, 1967; Upadhyay, Rekib and Pathak, 1974; Jones, Blunt and Nurnberg, 1978). From these pen-feeding studies it is clear that leucaena as the sole source of feed for ruminants does not compare favourably with lucerne even though the chemical composition and digestibility values are similar.

The reason for this difference is probably associated with the toxic effect of leucaena, which is discussed later. Compared with its use as the sole feed for ruminants, mixtures of leucaena and other roughages have given excellent results.

TABLE 1. **Concentration of elements in various plant parts of *Leucaena leucocephala* cv Peru** [1]

Plant part	N	P	S	Ca	Mg	Na	K	Cu	Zn
	(Percentage)							*(ppm)*	
Shoot tips	4.8	0.38	0.33	1.18	0.41	0.07	1.7	9	44
First expanded leaf	4.4	0.21	0.27	0.66	0.31	0.03	1.5	7	29
Fifth expanded leaf	4.2	0.16	0.25	0.49	0.20	0.03	2.6	11	30
Tenth expanded leaf	3.8	0.15	0.23	0.50	0.17	0.02	2.1	7	28
Green stem (< 6 mm diam)	2.1	0.22	0.16	0.36	0.21	0.05	1.9	9	36
Older stem (> 6 mm diam)	1.2	0.14	0.10	0.21	0.15	0.02	0.9	5	20
Flower heads	5.0	0.40	0.40	0.39	0.18	0.04	2.7	9	40
Pods	3.8	0.40	0.46	0.28	0.24	0.04	1.5	10	40

[1] Regrowth shoots approximately 1-m long, sampled at Samford, southeast Queensland in May (autumn).

TABLE 2. **Comparative composition of leucaena leaf and lucerne (alfalfa) leaf meal**

Component	Unit	Leucaena leaf	Alfalfa leaf
Total ash	(percent)	11.0	16.6
Total N	(percent)	4.2	4.3
Crude protein	(percent)	25.9	26.9
Modified acid/detergent fibre	(percent)	20.4	21.7
Calcium	(percent)	2.36	3.15
Phosphorus	(percent)	0.23	0.36
β-carotene	(mg/kg)	536.0	253.0
Gross energy	(kJ/g)	20.1	18.5
Tannin	(mg/g)	10.15	0.13
Amino acids	(mg/gN)		
Arginine		294	357
Cystine		88	77
Histidine		125	139
Isoleucine		563	290
Leucine		469	494
Lysine		313	368
Methionine		100	96
Methionine + cystine		188	173
Phenylalanine		294	307
Threonine		231	290
Tyrosine		263	232
Valine		338	356

Source: NAS (1977).

Use of leucaena as a cut forage for beef production. Leucaena cut from natural stands growing in the Philippines and in Indonesia has been traditionally used for fattening cattle. In the Philippines chopped leucaena shoots mixed with rice bran are used for finishing cattle for slaughter. During this phase of fattening the animals are force-fed using the mixture of rice bran and leucaena as a slurry in water. Similarly, in parts of Indonesia and Timor cattle are fattened for approximately six months on a diet essentially of leucaena and the pseudostems of bananas. There is a complete absence of data on the merit of these feeding systems compared with others, but it is clear from such practices, which have continued for many years, that the local people appreciate the value of leucaena in finishing cattle for slaughter.

In Thailand the use of leucaena in backyard plantings for supplementing the diets of animals when these are corralled underneath the houses at night is being encouraged (Shelton, 1977). The higher soil fertility around homesteads would enable vigorous growth of leucaena to take place while its value as a supplement during the dry season, in combination with rice straw and crop residues, would be an important adjunct to the diet of both working animals and fattening animals under such conditions.

TABLE 3. **Chemical composition and digestibility of the components of leucaena leaf material**

Component	Percent on dry matter basis	Digestibility [1] in vivo
Dry matter	34.5	71.4
Crude protein	21.5	78.0
Ether extract	6.5	47.6
Crude fibre	14.3	56.7
Nitrogen-free extract	49.5	81.1
Ash	8.28	—
Ca	2.70	—
P	0.17	

Source: Upadhyay, Rekib and Pathak (1974).
[1] Determined with goats.

Experimental results confirm the value of leucaena as a supplement to roughages low in protein to improve animal production. For example, Leng and Preston (1976), and Siebert, Hunter and Jones (1976) showed that supplementing a diet of chopped sugar cane with leucaena, so that the overall protein content of the diet was 9 percent, gave daily liveweight gains of 0.6 kg/head, identical to steers fed sugar cane and meat meal with an overall crude-protein content in the diet of 10 percent (see Table 4).

Steers given fresh leucaena daily as a 20 percent supplement to sorghum hay also had higher liveweight gains even when the total feed was restricted to 2.5 percent of the body liveweight in all rations. After 112 days on the rations, liveweight gain (LWG) of the control growth was 35 kg, for the animals on 20 percent leucaena it was 58 kg and for those on 80 percent leucaena it was 11 kg. Mean daily dry matter intakes for the three diets were 3.85 kg for the control growth, 3.91 kg for the animals on 20 percent leucaena and 1.99 kg for those on 80 percent leucaena. The efficiency of the diet containing 20 percent leucaena was far higher at 7.62 kg feed/kg gain than that of the sorghum hay diet — 12.3 kg feed/kg gain (R.J. Jones, unpublished data).

Terminal shoot of leucaena showing inflorescences and bi-pinnate leaves.

As a supplement to rice straw, leucaena fed to bulls has enabled reasonable gains to be achieved. Daily gains of 0.53, 0.38 and 0.36 kg/day resulted from feeding 60 percent rice straw + 40 percent concentrates, 60 percent rice straw + 40 percent dry leucaena leaf, and 10 percent rice straw + 90 percent leucaena leaf respectively (Perez, 1976). The bulls gained no more weight when leucaena comprised 90 percent of the ration than when it contributed only 40 percent. For fattening animals a reduction in the amount of rice straw was beneficial — a ration of 50 percent rice straw + 50 percent concentrates supported daily liveweight gains of 0.54 kg, compared with 0.71 kg when the ration was composed of 35 percent rice straw + 35 percent leucaena leaf + 30 percent concentrates (Perez, 1976).

Sun-dried leucaena leaf has been used to supplement grazing during the dry season in Malawi. Supplemented steers gained more than the

Tethered Bali bull near Kupang in Timor being fed leucaena, banana stem, kapok leaves and mimosa leaves. The bulls are fattened over a period of six months before they are ready for market.

controls but gains were not significantly different from those obtained with a supplement of groundnut cake fed to provide the same level of crude protein as in the leucaena (Thomas and Addy, 1977).

Leucaena has also been used in intensive fattening rations in combination with forage and energy supplements. In Malawi zebu and zebu-cross Friesian steers fed a ration of maize stover, maize bran and leucaena in the ratio of one part of leucaena to four parts of maize stover and maize bran, gained 1.17 kg per head per day. Used as a protein supplement in this way, leucaena has been as efficient as groundnut cake (Thomas and Addy, 1977). In these rations, the leucaena was fed as leaf meal produced by sun-drying the long shoots cut from leucaena. These shoots are dried on the leucaena "stubble", which may be up to 30 cm in height.

Intensive use of molasses and urea for fattening cattle requires some form of true protein, preferably by-pass protein, for good liveweight gains (Preston and Willis, 1970). Leucaena, which has fairly low protein solubility in the rumen, has proved to be an effective supplement for use with urea-molasses for intensive beef production (Alvarez, Wilson and Preston, 1977). In addition, the β-carotene content of leucaena would be a distinct advantage for such high energy rations, which require high levels of vitamin A for satisfactory animal performance (Preston and Willins, 1970).

In summary, where leucaena has been fed as a protein supplement with other feeds there have been no toxic effects on the animals and the beneficial effects recorded have been comparable with those derived from concentrated protein sources such as groundnut cake and meat meal.

Leucaena/grass pasture for grazing. Where leucaena is intended for grazing rather than for cutting, it is usual that the leucaena be sown with an appropriate grass to provide a balanced ration. Grasses that have been found suitable for this purpose are guinea, pangola and signal. The leucaena is usually planted in rows 2-3 m apart with the grass forming an "understorey" between the leucaena rows. Grown in this way, leucaena can be used as a grazed supplement or as the sole pasture for beef or milk production. As a supplement, the leucaena area would normally be subdivided into four or more areas that can be used in rotation with another sown pasture (Shaw, 1968) or native pasture (Partridge and Ranacou, 1974). In Fiji, paddocks of Nadi blue grass (*Dichanthium caricosum*) in which nil, 10 or 20 percent of the area was planted with fertilized leucaena, were grazed at 1.5 steers per hectare to measure animal production. Daily liveweight gains over a three and a half year period were 215 g on the grass pasture, 300 g on the 10 percent and 500 g on the 20 percent leucaena pastures (Partridge and Ranacou, 1974) (Table 5).

At Gayndah in Southeast Queensland on clay soils of basaltic origin and in an area with 710 mm annual rainfall, supplemental paddocks of leucaena have resulted in large increases in animal production. On native pastures at a stocking rate of one cow to 3.1 ha, where 0.4 ha of the area was planted to leucaena for winter spring grazing, the cows with access to leucaena had higher weight gains and a conception rate of 80 percent compared with 59 percent for controls. Steers allocated 0.2 ha per head of leucaena in addition to native pasture gained 114 kg more liveweight over a 17-month period than control steers on native pasture only (Queensland Department of Primary Industries, 1978).

The leucaena area in the supplemented treatments comprised one paddock to which access was allowed for one to two days per week on the 10 percent leucaena treatment and three to four days per week for the 20 percent leucaena treatment. Over the experimental period, gains per head and per hectare declined on the control treatments but remained reasonably stable for the leucaena supplemented treatments. It can be calculated that 1 ha of supplemental browse contributed 600 kg LWG/annum for the 10 percent leucaena treatment and 800 kg LWG/annum for the 20 percent leu-

Bali bull and goat near Kupang in Timor. This bull has only just begun the intensive feeding for fattening.

caena treatment. The persistence of the legume under these conditions and the fertilizer-sparing aspects of using supplemental leucaena pastures were characteristics that led to it being recommended for use by local farmers. Where labour is readily available and where leucaena can be grown successfully, animal production can be more than doubled by this simple strategy of improvement.

When leucaena-based pastures have been the sole feed for grazing cattle results, in terms of animal performance, have been rather conflicting. Henke (1958) in Hawaii reported gains of 233, 171 and 90 kg per hectare per year in three consecutive years at a stocking rate of 1.24 steers per hectare. The rainfall for these three years was 1 800, 860 and 510 mm. No ill effects were reported in the stock grazing of these pastures and the reduced animal production over the three-year period was obviously associated with the decreasing rainfall. Under irrigation, on a calcareous clay loam in the Ord Valley of Western Australia, cattle grazing leucaena/pangola pastures stocked at 6.2 beasts per hectare had mean liveweight gains per day of only 0.37 kg. Production per hectare per annum of 830 kg at this stocking rate might be considered good, but the animals had clinical signs of leucaena toxicity and were clearly unthrifty (Blunt, 1976). At the lower stocking rate of 4.9 beasts per hectare, the animals gained only 0.33 kg per head per day and the clinical signs of toxicity were more marked and associated with a greater intake of leucaena. In a subsequent experiment at this site, at a stocking rate of 5.6 steers per hectare, mean gain was only 0.29 kg per head per day and animals showed signs of clinical toxicity. For the first three months on leucaena, gains of animals were good, approaching 1 kg per head per day. Weight gains then declined and the severity

TABLE 4. **Feed intake and liveweight (LW) gain of weaner steers fed sugar cane with meat meal or leucaena as a supplement**

Kilograms

Intake	Sugar cane + meat meal		Sugar cane + leucaena	
Sugar cane	9.4	(3.4)	5.6	(2.05)
Leucaena	—		4.5	(1.45)
Meat meal	0.7	(0.4)	—	
Total	10.1	(3.8)	10.1	(3.5)
Total N per day	0.69		0.53	
LW gain per day	0.61		0.61	

Source: Siebert, Hunter and Jones (1976).

NOTE: Fresh weights given. Weight of organic matter shown in brackets ( ). The weaner steers ranged from 137-168 kg liveweight. Crude-protein percentages: sugar cane 2.2, leucaena 18.2 and meat meal 54.4.

Hereford steer grazing leucaena/setaria pasture in the subtropics of southeast Queensland. Such steers gained 1.0 kg per head per day over a 215-day period with no supplementary feeding.

of the symptoms of toxicity increased. The clinical signs were related to the length of time animals grazed leucaena. Animals that were rotated between pure pangola-grass pastures and leucaena/pangola pastures gained far more weight when they returned to the leucaena-based pasture than did animals grazing the leucaena pastures full time. It was postulated that cumulative toxicity occurred when animals grazed the leucaena for prolonged periods but that this was alleviated when the animals were removed from the pasture; their subsequent return enabled them to gain more weight than counterparts grazing on leucaena continuously (Blunt and Jones, 1977).

In the subtropical environment of southeast Queensland, steers make good gains on leucaena/rhodes grass pastures in most years. In some years toxicity, including hair loss, occurs in late summer and this is associated with a decline in weight gain. In this environment the adverse effects of leucaena are not as great as those in the more tropical conditions experienced in the Ord Valley (Jones, Blunt and Holmes, 1976). Under continuous grazing at a stocking rate of 1.9 steers per hectare, mean weight gain over a 3.4-year period was 0.49 kg per head per day, or 340 kg per hectare per annum. This production was approximately 50 percent higher than for pastures of setaria and siratro (the most reliable alternative tropical pasture) grown on the same soils and at a similar stocking rate (R.J. Jones, unpublished data).

When the same leucaena/rhodes grass area was subdivided and grazed four-weeks-on, four-weeks-off, yields of leucaena increased and it was possible to increase the stocking rate from 1.9 to 2.5 steers per hectare year long. Gains under this system have averaged 327 kg/ha/year for the last five years of a lower than average rainfall. This pasture is now 20 years old and is still extremely productive.

TABLE 5. **Liveweight gain of steers grazing Nadi blue grass** *(Dichanthium caricosum)* **pastures alone or with supplementary areas of leucaena in Fiji**
(Grams per day)

Treatment	Year 1	Year 2	Year 3	Mean
Grass grown alone	280	200	170	215
	(150)	(105)	(95)	(110)
Grass with 10% of area in leucaena	315	255	340	300
	(170)	(145)	(185)	(170)
Grass with 20% of area in leucaena	510	490	510	500
	(275)	(260)	(289)	(270)

Source: Partridge and Ranacou (1974)
NOTE Pastures stocked at 1.5 steers/ha Bracketed figures refer to kg/ha/year.

Brahman bulls browsing leucaena over which Centrosema pubescens *is climbing. The combination of small areas of leucaena in conjunction with hill pastures in Fiji has doubled beef production per hectare.*

In another study in subtropical southeast Queensland, the remarkably high mean daily gain of 0.93 kg/head/day for two-year-old steers and 0.88 kg/head/day for calves over a 200-day grazing period was recorded on leucaena/Nandi setaria pastures. These animals received only iodized salt supplements (Jones, 1973). When slaughtered the steers had very yellow fat, markedly more pigmented than normal pasture-fed steers and undoubtedly due to the high levels of β-carotene in the leucaena leaves.

The wide range in mean daily gain (0.29 to 0.93 kg) when steers graze leucaena-based pastures is associated with several factors. Environmental factors that influence leucaena growth are important, not only in determining the yield level and yield distribution throughout the year, but also in influencing the mimosine levels in the material grown. The intake of leucaena and the development of toxicity are also important and, perhaps, the most likely causes of the low gains reported on vigorous leucaena-based pastures in hot tropical areas.

Milk production from leucaena. Impressive yields of milk, both per cow and per hectare, have been reported from leucaena/guinea grass pastures in the tropics (Henke *et al.*, 1950; Plucknett, 1970). However, in both these studies, the dairy cattle were fed appreciable quantities of concentrates amounting to approximately one half of the total dry matter intakes. Even so, the leucaena/guinea grass pastures at the Mahalona hospital dairy on Kauai, Hawaii were able to carry a stocking rate of 6.1 large Friesian cows per hectare over a period of about 12 years with an annual average milk production per hectare of 9 770 kg with no indication of toxicity and no problems with breeding (Plucknett, 1970). Even more impressive was the performance of unsupplemented Jersey cows grazing leucaena/green panic (*Panicum maximum* var. *trichoglume*) pastures in southeast Queensland. At a stocking rate of 4.78 cows/ha over a nine — month period a yeld of 6 290 kg milk/ha was produced containing 272 kg butterfat and 215 kg protein (Stobbs, 1972).

Improvements in milk production when dairy cows were given small supplements of leucaena in addition to the well-fertilized rhodes grass pasture have been reported by Flores, Stobbs and Minson (1979). The increase due to leucaena occurred inspite of the fact that the fertilized pastures of rhodes grass contained over 20 percent crude protein. The effect of feeding 2 kg leucaena leaf per cow per day was equivalent to feeding 250 g per cow per day of protected protein (formal casein).

Leucaena is known to taint the milk produced from cows grazing it (Henke, 1958). Such taint can be reduced by ensuring that cows do not graze the leucaena pasture for several hours before milking.

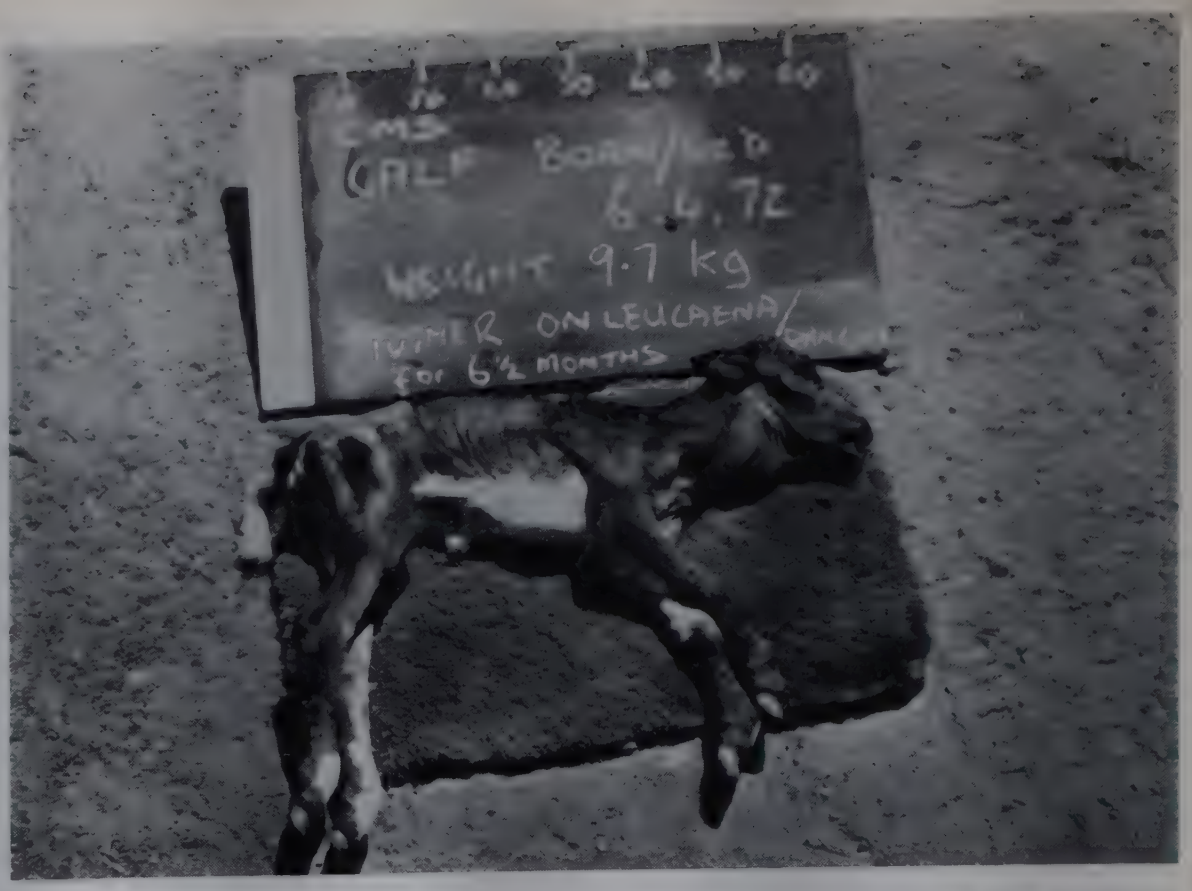
Rejection of such tainted milk is not necessary under commercial conditions since the processing of the milk at the factory is sufficient to remove the taint and odour to acceptable levels (Hamilton, Fraser and Armitt, 1969).

Toxicity of leucaena for ruminants. The toxic amino acid mimosine occurs

in all parts of the leucaena plant. Concentrations in the growing tips may attain a level of 12 percent of the dry matter, in young leaves 3 to 5 percent, in pods 3 to 5 percent and in seeds 4 to 5 percent of the dry matter. Green stem may contain up to 2 percent mimosine but older stem that has become subereous has usually less than 1 percent of mimosine in the dry matter.

The toxic action of mimosine in non-ruminants has been well known for many years. Mimosine is also toxic to ruminants. Sheep unaccustomed to leucaena, shed their wool approximately 7 to 14 days after leucaena feeding commences; continued heavy feeding may result in death (Hegarty, Schinkel and Court, 1964; Reis, Tunks and Hegarty, 1975). If ruminants are gradually introduced to leucaena, rumen micro-organisms capable of breaking down the mimosine increase so that the toxic action of mimosine no longer poses a problem. In a study (Shiroma and Akashi, 1976) rumen fluid from goats degraded the mimosine in leucaena tips from 60 to 0.3 mg/g after 25 hours and, with pure mimosine, 98 percent was degraded by the rumen fluid after 5 hours. The obvious clinical sign of toxicity in the ruminant is alopecia (hair loss), which occurs sporadically when cattle are introduced to leucaena for the first time or when they receive rations containing high amounts of leucaena. Goats are said to be unaffected (Kraneveld and Djaenoedin, 1947; Owen, 1958). However, experiments with goats in Queensland have shown that the goat is affected by leucaena and shows hair loss similar to that encountered with cattle (R.J. Jones — unpublished data).

In addition to the alopecia noted when animals first have access to leucaena, there are other reports in the literature of toxicity in animals that have grazed leucaena for long periods. Clinical signs include alopecia, loss of appetite, excessive salivation, incoordination of gait, enlarged thyroid glands, poor breeding performance and the production of goitrous calves that die at birth (Compere, 1959; Letts, 1963; Hamilton, Donaldson and Lambourne, 1968; 1971; Vohradsky, 1972; Jones, Blunt and Holmes, 1976; Holmes, 1976; Jones, Blunt and Nurnberg, 1978).



Calf born to cow grazing leucaena pastures for six and a half months during pregnancy. The swelling in the neck is due to the grossly enlarged thyroid glands.

High levels of selenium were once thought to be implicated in the toxicity exhibited by experimental animals fed on leucaena (Arnold, 1944; Gardner and Bennetts, 1956). This hypothesis has not been substantiated either in Hawaii (Yoshida, 1945) or in Australia (Hutton and Gray, 1959). The leaves are reported to contain hydrocyanic acid (HCN) (Quisumbing, 1949, quoted by Oakes, 1968) but its presence in leucaena has not been substantiated in Australia, where it had been considered as a possible reason for the enlarged thyroid glands noted in animals grazing leucaena pastures (R.J. Jones, unpublished data).

It is now apparent that the chronic toxicity of leucaena for ruminants is related only indirectly to its mimosine content. Generally speaking, mimosine toxicity *per se* is not the major problem. It has now been shown that DHP (3-hydroxy-4-1(H)-pyridone), the breakdown product of mimosine in the rumen, is a potent goitrogen (Hegarty *et al.*, 1976). DPH may also have other undesirable effects but its goitrogenicity is now without question. Circulating DHP prevents iodination of tryosine, the first step in the synthesis of thyroxine, resulting in goitre and reduced levels of thyroxine (T_4) in the serum. This depressed thyroxine level has other side effects that may be associated with the reduced appetite, drooling and even hair loss that were noted in cattle fed high levels of leucaena in Australia and New Guinea (Jones, Blunt and Holmes, 1976).

All clinical signs are not consistently present when animals are fed diets high in leucaena — for example, Hamilton, Donaldson and Lambourne (1971) reported that leucaena did not affect oestrous cycle length, conception rate or gestation length in heifers. The only adverse effects noted were slight depilation, some mild incoordination and nervous symptoms occurring briefly during gestation, and lower mean birth weight of calves (19.6 kg versus 25.8 kg for the lucerne control diet). Calf thyroid glands were also enlarged and plasma-bound iodine levels elevated. The histology of the thyroid gland was, however, normal.

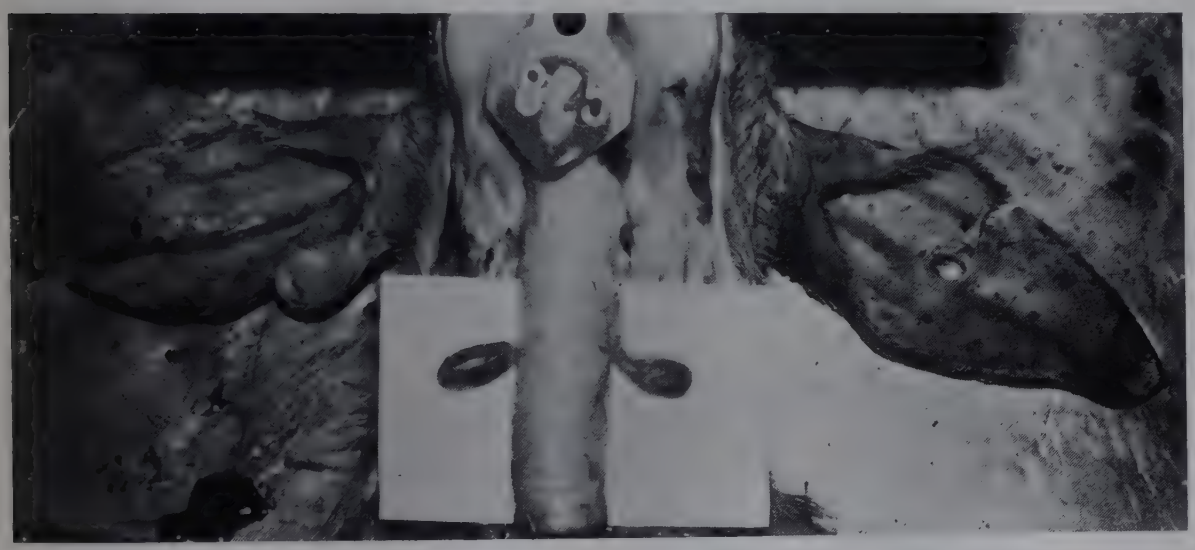
Large thyroids were also noted in lambs born to ewes fed leucaena (Bindon and Lamond, 1966), but Little and Hamilton (1971) were unable to repeat this observation. The lack of any adverse effect on conception rates in the study of Hamilton, Donaldson and Lambourne (1971) confirmed the

work of Henke *et al.* (1950) in Hawaii where, for three successive lactations in cows fed diets of leucaena and concentrates, the animals bred normally. They are also in accord with the results from an experiment extending over five years in which Hereford and Hereford × Afrikander heifers that were reared and mated on leucaena-based pastures gave conception rates of over 90 percent (R.J. Jones, unpublished data). However, Holmes in New Guinea reported low conception rates and poor growth in Brahman cross heifers grazing a predominantly leucaena pasture containing some unpalatable weeds (Holmes, 1976). These apparently conflicting reports may be the result of the different intakes of mimosine by the cattle in the different experiments. For example, in the study by Hamilton, Donaldson and Lambourne (1971) the overall mean concentration of mimosine in the dry material ranged from 0.34 to 1.2 percent. This compares with values of 3-4 percent in studies where problems have occurred (Jones, Blunt, Holmes, 1976; Jones, Blunt and Nurnberg, 1978). The conflicting results for heifers in southeast Queensland and in New Guinea could also be due to the fact that in the Australian study the animals grazed a fertilized mixed pasture of leucaena and setaria whereas those in New Guinea were confined to unfertilized leucaena.

Unfortunately the mimosine concentration of the diets fed has not been measured in many experiments. Part of the variability encountered between animals grazing the same leucaena pasture is undoubtedly due to the different proportion of leucaena selected by the different animals. Estimation of the proportion of leucaena selected by 10 steers grazing the same leucaena/pangola pasture, using C^{12}/C^{13} ratio in the faeces (Jones *et al.*, 1979) showed that individual animals selected from 30 to 70 percent of leucaena in the diet. Furthermore, animals that selected lower amounts of leucaena had low toxicity scores and those that selected high amounts of leucaena had high toxicity scores (R.J. Jones, unpublished data).

In studies where the level of leucaena in the diet of steers was varied from zero to 100 percent, rations containing up to 40 percent of leucaena resulted in good liveweight gain over a period of 112 days although the T_4 levels in the serum of cattle on the 40-percent leucaena diet decreased to less than 20 n mol/litre by the end of the feeding period. Steers on the zero percent, 10 percent and 20 percent leucaena diets maintained normal T_4 levels of 60-100 n mol/litre throughout (Jones, 1977). It is, therefore, suggested that diets containing less than 30 percent of leucaena would not be expected to cause toxicity problems in growing stock.

One notable feature of the toxicity of leucaena to animals is its ready reversibility when the animals are removed to a non-leucaena pasture. Cessation of leucaena feeding results in a rapid return to normal T_4 levels and, provided the animals have not been unduly stressed prior to the change of feed, their growth rates return to normal (Jones, Blunt and Nurnberg, 1978). The toxicity is not acute under field conditions — there is no known record of animals dying while grazing leucaena — deaths that that have occurred were reported from pen feeding studies where leucaena was fed as the sole ration. Under field conditions, sick animals are recognized readily and can be removed to non-leucaena pastures. In this respect, white clover and lucerne, which cause bloat in temperate pastures, are a far greater risk in terms of stock losses than is leucaena.



Exposed thyroid glands from goat fed a grass ration for 105 days. The glands weighed 1.15 grams.

Exposed thyroid glands from goat fed leucaena for 105 days. Note the very pronounced vascularization of the isthmus region. The glands weighed 7.8 grams.

Problems of acceptance as a forage species. A plant that, on the one hand has such a high potential for producing protein and yet on the other is not being utilized to any great extent for animal production, must have certain limitations that prevent this potential being fulfilled. What are the factors limiting its usefulness as a

forage species? It is suggested that there are several:

- The plant is very slow to establish, even under extremely good conditions, compared with other pasture legumes and, as such, succumbs to weed competition in many situations (Hills, 1971). In addition, establishment can be hindered dramatically because of its extreme palatability both to marsupials and to domesticated ruminants such as the goat;
- The plant is not adapted to acid, poorly drained soils of low base status, which occur widely in the tropics;
- There are fears about the adverse effects of leucaena on grazing livestock. The toxicity of this plant has been discussed above;
- Being a shrub or tree, its utilization and management may be very different from that of the traditionally used legumes in pasture development. This is particularly true in the grazed (as opposed to the cut-and-carry) system;
- Lack of appreciation of the animal production capacity of systems that include leucaena as the key legume component. The reviews of Gray (1968) and Hill (1971) highlight the paucity of information on the animal production aspects of leucaena as a forage species. The situation is somewhat improved now (1979) but information is far from complete. This lack of information concerning animal production in specified production systems is undoubtedly one of the major factors limiting the use of this very valuable species.

The future. There is a real need for further studies to assess the animal production potential of leucaena relative to alternative feeds. Most studies document the production of leucaena without reference to viable alternatives. In any situation there needs to be clear advantage for leucaena if the extra effort of establishing and maintaining the plant is to be made. The advantages claimed for leucanea may be real, but unless they are documented in terms of increased animal productivity and economic gain there will be very little incentive for a wider utilization of the plant for ruminants.

The greatest immediate potential would appear to be in Southeast Asia where most of the livestock are maintained on smallholdings (Guzman, 1978). In such situations, the use of improved cultivars of leucaena could provide valuable protein and mineral supplementation to the cereal-crop residues fed to ruminants. Under these conditions the low proportions of leucaena fed would obviate any toxicity problems.

If productive low-mimosine cultivars (Hutton and Bray, 1977) are produced they will remove one factor that has served to limit the use of leucaena for intensive animal production. It would then be more readily accepted in grazing systems where limitation of intake to control toxicity may be difficult to achieve. A reduction in the possible weed-potential by means of less "weedy" cultivars, or the use of sterile hybrids (*L. pulverulenta* × *L. leucocephala*), could also result in wider acceptance of the plant in areas of South America, Africa and Australia where livestock are grazed under range conditions rather than fed cut forage. ■

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Bali cattle in Australia

G.W.M. Kirby

Bali cattle, often referred to as *banteng*, have been classified according to various synonyms (*Bos javanicus*, *Bos* (*Bibos*) *banteng*, *Bos* (*Bibos*) *sondaicus*). Together with the Gaur (*Bos* (*Bibos*) *gaurus*) and the Kouprey (*Bos* (*Bibos*) *sauveli*), Bali cattle represent the indigenous bovine species of the Southeast Asian region (Payne, 1970). To the south of this region lies the northern Australian coast (Figure 1), where Bali cattle have provided one of the more unusual episodes in the history of cattle.

In Southeast Asia, Bali and Bali-cross commercial cattle are mainly found in Indonesia (Payne and Rollinson, 1973).

Historical. Historical records reveal that 20 Bali cattle were shipped from the Indonesian island of Bali to the Port Essington army settlement on the Cobourg Peninsula of the Northern Territory of Australia in January 1849 (Calaby, 1975). During the settlement's existence, Timor ponies, pigs, poultry and water buffaloes (*Bubalus bubalis*) were also introduced. All these species were exotic to this part of Australia.

Shortly after the introduction of Bali cattle, the small army settlement was abandoned; all the livestock were left behind to fend for themselves. These Bali cattle were forgotten for over a century until, they were rediscovered in 1960 (Letts, 1964). During this period they had lived in a feral state (Figure 2) in virtual isolation on the Cobourg Peninsula and in the absence of any other cattle breeds. By contrast, most of the buffaloes quickly migrated off the Cobourg Peninsula and rapidly and successfully colonized the wet, coastal plains to the south.

The Bali cattle on the Cobourg Peninsula inhabited those areas adjoining treeless grass-and-sedge plains and forest habitats (Figure 3). Apparently this feral population has remained relatively stable and in harmony with the natural ecosystems of the areas. It is unlikely that it has ever exceeded 3 000 head.

The rediscovery of the Bali cattle sparked interest and speculation as to whether or not they might be potentially valuable in replacing or improving the poorly adapted and unproductive *Bos taurus* (Shorthorn) cattle in monsoon Australia. This led, in 1961, to the first of several expeditions (Figure 4) to the Cobourg Peninsula to capture Bali cattle and transfer them to the Coastal Plains (Beatrice Hill) Research Station, 75 km east of Darwin. There, a programme of redomestication, crossbreeding and research started.

Coastal environment. The climate is distinctly wet-monsoon. The yearly rainfall is approximately 1 350 mm with 95 percent falling in a six-month wet season (November-April). Average temperatures are high in both wet (28.6°C) and dry (25.8°C) seasons. Humidity is higher in the wet season (74 percent) than in the dry season

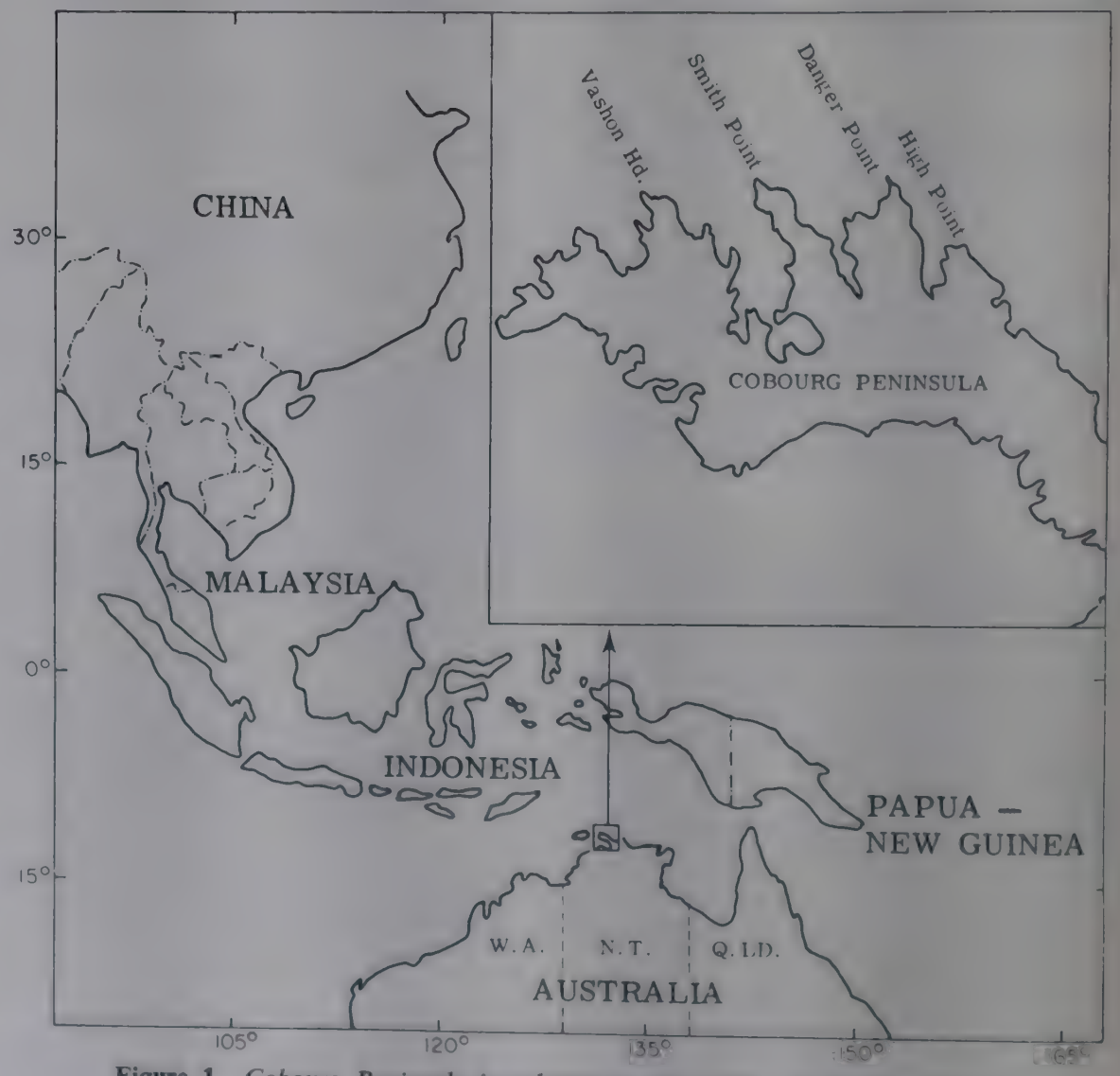

Figure 1 *Cobourg Peninsula in relation to Australia and Southeast Asia.*

G.W.M. Kirby is Principal Animal Production Officer and animal geneticist with the Division of Primary Industry, Darwin, Northern Territory 5794, Australia.

Figure 2 *Feral Bali bull in the monsoon forest on Cobourg Peninsula.*

Figure 3 *Preferred Bali cattle habitat on Cobourg Peninsula.*

(64 percent). The growing season of the native pastures is less than six months and their protein content is usually below 6 percent. Internal and external parasites and infectious diseases are present, and have varying effects on production. Predators include dingoes, crocodiles, and pigs, depending on the habitat.

Straight-bred production. Little information was available on Bali cattle, and so the initial research priority was to obtain basic production data (Figure 5). To help define their potential, the performance of Bali cattle was compared with a contemporary Brahman/Shorthorn breeding herd for three years up to 1970.

Bali calves are small and weigh about 17 kg at birth, compared with 30 kg for the Brahman/Shorthorn calves; they grow very slowly when the herd is run on pasture. Growth rates during the first six months (0.22-0.27 kg/day) are only about 30 percent of those of the Brahman/Shorthorn calves (0.68-0.82 kg/day). The milk production of Bali cows (1.87 litres/day), measured by a tritiated-water technique, was only one-quarter of that of Brahman/Shorthorn cows. Relative to body weight milk consumption by Bali calves was still only 40 percent (67 ml/kg/day) of that of Bali/Brahman and Brahman/Shorthorn calves. However, there were no differences, within the errors of measurement, between straight-bred Bali and other-genotype calves in their efficiency of conversion of milk to body solids or liveweight.

As growth continues, the liveweight of Bali cattle remains low compared with that of Brahman/Shorthorn cattle. Comparable measurements include a liveweight gain on improved pastures of 65 kg and 121 kg for the first 12 months of age and mature liveweights of 298 kg and 409 kg for Bali and Brahman/Shorthorn cows respectively. However, relative to mature liveweight, the liveweight advantage of the Brahman/Shorthorn yearling is reduced to approximately 8 percent. The slower growth and smaller mature size of Bali cattle do not necessarily imply a lower efficiency of feed use. Bali cattle at all ages have an ability to maintain body weight (Moran, 1973) and body condition even when pasture quality becomes poor. In this attribute they are superior to other cattle in the Northern Territory. Cows lose less body weight and condition during lactation than their Brahman/Shorthorn contemporaries, thanks to their lower milk production.

Figure 4 *Bali cattle held in yards shortly after their capture from feral herds.*

Bali cattle normally have very high conception-rates despite the monsoon-induced environmental stresses. They regularly achieve 90-100 percent conception compared with the expected 60-70 percent for the contemporary Brahman/Shorthorn cattle. This probably reflects the better ability of the Bali cattle to maintain good body condition, low milk production and, possibly, a longer duration of oestrus.

Because of the slow growth rates in this environment, the Bali heifers do not normally conceive under 36 months of age, compared with approximately 24 months for the

Brahman/Shorthorn contemporaries.

Unfortunately, net reproduction-rates in Bali cattle in this environment are low, due to the high mortality — up to 80 percent — of the young stock (birth to 16 months), compared with 0-10 percent for Brahman/Shorthorn cattle. The basic causes of this high rate of loss are the low milk-production and adverse behavioural patterns of Bali cattle. These losses, which occur under extensive herd management, do not tend to occur under individual animal management systems. Bali cows and the young stock are very timid and can be easily upset. As a result, young animals leave the herd during mustering or disturbance; they run into yard panels when stressed, causing head and spinal injuries; and they easily get into states of shock, with subsequent complications.

The dam-calf bond is weak, resulting in a lack of adequate protection from predators. This weak bond also predisposes cattle to an apparently high degree of cross-suckling, which can easily lead to milk deprivation in newly born calves. Because of the behavioural and mortality problems, it is preferable not to wean calves. Other aspects of herd productivity appear to be unaffected by not weaning.

Bali cattle become quieter with frequent and close handling. However, for systems under extensive herd management (labour is limited in Australia) animals that have been well trained will revert under such management to a nervous, shy nature within about three weeks. Bulls (Figure 6) after sexual maturity, however, become quiet and easy to handle.

With bulls in the herd all the year round there is a distinct and regular mating/calving season (September-December/June-September) in this environment. This pattern is remarkable because the mating season occurs in the driest and poorest feed period of the year. Photoperiodicity effects (possibly on libido) may be operating to produce this pattern. However, because the survival of calves has been lowest when they are born early in the dry season, a mating season restricted to three months in the mid-wet season has proved preferable and has not reduced fertility in the experimental herd.

Figure 5 *Experimental herd of Bali cows and calves being handled in yards.*

Dissection of a single 2½-year-old steer from the herd showed several distinctive anatomical features. Compared with other cattle breeds the Bali has a much higher proportion of its muscle weight in the hindlimb (23 percent) and around the spinal column (3 percent) and less muscle-weight in the forequarter (10 percent) and abdominal wall (24 percent) (Berg and Butterfield, 1976). A markedly greater (39 percent) development of the distal muscles of the limbs probably accounts for the agility of this species, while the lower weight of muscles in the abdominal wall is more typical of non-domesticated species. The dressing percentage of the steer (52.6 percent) was higher than that of a comparable buffalo steer (44.1 percent). Charles, Johnson, and Butterfield (1970) recorded similar dressing percentages in buffaloes and Brahman/Shorthorn cattle.

The fat of the Bali tends to be yellow in colour and is softer than in other cattle. Fat deposition is minimal, yielding a type of meat that consumers prefer. Fat content is, however, adequate for purposes of cooking. Two eight-year-old steers (averaging a carcass weight of 262 kg) had approximately 55 percent fat cover and 1 cm fat depth over the twelfth/thirteenth rib.

Crossbreeding. Crossbreeding experiments were begun in 1967, after the production of a single first-cross calf in 1965 (Letts, Kirby and Hayes, 1968). By 1970 sufficient data had been collected to indicate an exciting potential for the cross. By this time, also, Australians were becoming more aware of Bali crossbreeding in Indonesia. A programme to evaluate various Bali × Brahman/Shorthorn crosses systematically, and ultimately to produce a synthetic breed, was started. The initial breeding plan is shown in Figure 7.

No problems were encountered in mating Bali bulls to Brahman/Shorthorn cows. However, attempts to mate Brahman/Shorthorn bulls to Bali cows were unsuccessful, the Brahman/Shorthorn bulls and Bali cows remaining voluntarily segregated in the paddock. Artificial insemination was then successfully carried out. Difficulties were, however, experienced at or near birth, resulting in the death of all five F_1 calves and two of the Bali dams.

Successful attempts to mate Brahman/Shorthorn bulls to Bali cows were subsequently achieved in Timor and Sulawesi (Leake and Nicholson — personal communications).

The fertility of the F_1 cows has been high — 90 percent, compared with 70 percent for Brahman/Shorthorn cows. Preliminary results from

Figure 6 *Mature Bali cattle bulls of mixed ages, showing the characteristic white marking of legs and hindquarters.*

1/4 Bali and 3/4 Bali heifers indicate a much lower fertility than that of F_1 heifers. This is due, possibly, to delayed maturity.

All F_1 bulls (Figure 8) proved sterile and their sperm development ceased at the secondary spermatocyte stage. Such male sterility is common in a number of other Bos species hybrids (Gray, 1972). Infertility also exists in both 1/4 Bali (Figure 9) and 3/4 Bali (Figure 10) bulls, although some sperm were present in 1/4-Bali semen.

Because of F_1 bull sterility, it has not been possible to proceed directly to F_2 progeny by intermating F_1 animals. Hence the emphasis in the breeding programme has been changed and placed on the evaluation and development of the back-crosses until such time as some fertile crossbred-males are found among them.

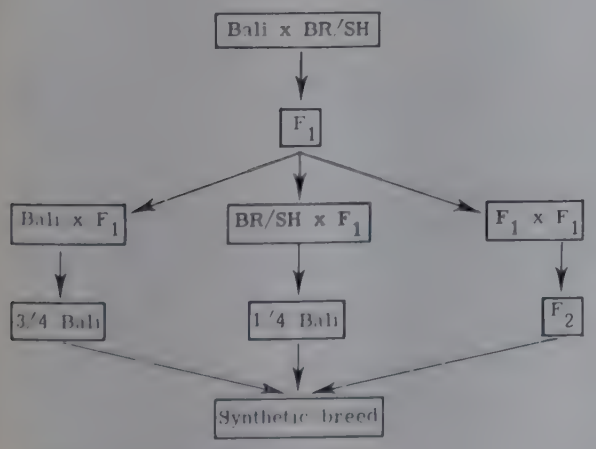

Figure 7 *Breeding plan for a Bali × Brahman/Shorthorn synthetic breed (development to depend on the source(s) of fertile Bali-cross bulls). BR/SH = Brahman × Shorthorn.*

The F_1 calves at birth are very strong and vigorous and, combined with the good milking-ability of the Brahman/Shorthorn dams, have very high survival rates, which remain so throughout life. The pre-weaning and post-weaning growth rates of F_1 and Brahman/Shorthorn animals are similar. The F_1 body-condition scores are higher than those of the Brahman/Shorthorn. In the first back-crosses, growth rates to weaning are approximately 12 percent lower than in the F_1. Following weaning, growth rates compared with the F_1 are approximately 32 percent lower for 1/4 Bali and 58 percent lower for 3/4 Bali yearlings. However, the 3/4 Bali generally maintain much better body condition than do the 1/4 Bali cattle.

F_1 animals combine strength and vigour with the nervous temperament of the Bali parent. This presents management difficulties especially under a herd system, when frequent attention is not possible. These traits are marked enough to reduce considerably their value in large-scale and extensive production. In the 1/4 Bali the temperament problem largely disappears, but in the 3/4 Bali temperament is very similar to the straight-bred Bali.

Chromosomes. Karyotype studies have shown the Y male sex-chromosome to be apparently identical to that of *Bos taurus* rather than to that of *Bos indicus* (Cartwright — personal communication). The number of chromosomes is identical to that of other cattle types.

Adaptation. The heat tolerance of Brahman/Shorthorn and Bali steers differed little in stationary trials but the Bali were more stressed by forced exercise (Moran, 1973). Cutaneous evaporation rates were 44 percent higher in Bali than in Brahman/Shorthorn steers, suggesting possible differences in the methods of heat dissipation. Suitability to the environment is undoubtedly enhanced by the reflective, short, sleek coat and black, pigmented skin of the Bali.

Under field conditions few adult cattle-ticks (*Boophilus microplus*) are observed on Bali cattle, except on those under extremely poor conditions of nutrition.

Helminth egg numbers in faeces appear to be comparable in Bali and Brahman/Shorthorn cattle. However, no information is available on the effects of helminths on production.

Early comparative-nutrition studies have not yet identified any distinctive physiological advantages in Bali cattle. Fasting metabolism and voluntary feed-intake per unit weight were higher in Bali than in Brahman/Shorthorn in a limited study by Vercoe and Frisch (1977). Moran, Norton and Nolan (1978) found no significant differences between Bali and Brahman/Shorthorn in voluntary feed-intake, faecal excretion of organic matter, cellulose and energy, and urinary excretion of nitrogen, phosphorous and energy; Bali cattle had a smaller rumen volume and a slower rumen flow rate. Water turnover in the Bali is slower (Siebert and MacFarlane, 1969) and water appears to be more efficiently utilized than in Brahman/Shorthorn cattle (Moran, Norton and Nolan, 1978). Obviously more work is needed in order to understand the ability of Bali cattle to maintain weight, good body-condition and to thrive so well on poor-quality pastures.

There is no data indicating that Bali

cattle have any superior resistance to infectious diseases.

Feral Bali population. Population and behavioural studies have commenced with the feral Bali (*banteng*) cattle on the Cobourg Peninsula. A preliminary survey has estimated the total feral population to number approximately 1 000 head (Graham, personal communication). The population is concentrated on two main areas to the south of both Smith Point and Danger Point (see figure 1), although isolated groups and indivduals are seen elsewhere. They share the range with varying numbers of buffaloes, Timor ponies, and deer. The population currently contains an excess of animals five to six years old and a negligible number older than ten years. The apparent herd decrease and current age structure reflect unstable herd-dynamics, probably resulting from the effects of human activity, including periodic captures, general effects of human presence and heavy culling practices. This instability follows a century of apparent stability which, combined with efficient ecosystem-use, resulted in few adverse effects due to factors such as overgrazing, erosion, trampling and destruction of water sources. This behaviour contrasts markedly with other feral grazing-animals such as buffaloes.

The compatability between feral Bali cattle and their habitat was also observed in Indonesia by the author and is reported by Sumardja and Kartawinata (1977) in Indonesia and by Wharton (1969) elsewhere in Asia. Subjective observations confirm that the production and behavioural patterns are generally similar in domesticated and feral herds.

The future. Historically, Australia has had three major introductions of exotic beef-cattle breeds. However, compared with the south, northern Australia has not been able to expand the genetic base of its cattle to the same degree because the desirable exotic, tropical breeds are mainly located in areas with major bovine diseases. This condition, together with the need for further genetic improvement of existing commercial cattle.

Figure 8 *Yearling first-cross bulls from Bali-bull × Brahman/Shorthorn-cow matings.*

Figure 9 *Yearling 1/4 Bali bulls sired by Brahman/Shorthorn bulls out of F_1 cows.*

Figure 10 *Yearling 3/4 Bali bulls sired by Bali bulls out of F_1 cows.*

emphasizes the need for the conservation of the new genes and gene combinations present in Bali cattle. In particular, the conservation and sound management of Bali cattle on the Cobourg Peninsula will be essential for some years to come. However, this single feral herd will remain susceptible to population reduction and movement restrictions if adverse environmental conditions or exotic-animal diseases occur. Attempts must therefore be made geographically to disperse the establishment of significantly large, viable breeding herds.

The future use of Bali cattle in Australia will depend partly upon current research results and partly upon future commercial management and production systems. Apart from the real aesthetic value of Bali cattle in the feral or confined state (e.g., in tourism), their production potentialities for Australia include:

- Their inclusion in straight-bred production systems that are small-scale and labour-intensive. The future importance of these, however, is likely to be small because such systems depend upon certain human social-structures and lifestyles. Furthermore, straight-bred production would not be a large scale (pastoral) proposition because of the slow growth rates, high calf mortalities and nervous temperament;
- Their inclusion in carefully developed crossbreeding-systems in order to utilize the advantages and hybrid vigour of the first cross. The prospects are particularly good for the production of F_1 slaughter males and F_1 females for the breeding of slaughter 1/4 Bali male and female cattle;
- Their inclusion in the development and use of one or more new synthetic-breed types — an objective of the current research programme. Many interfertile Bali-cross cattle, including the Madurese, exist in Indonesia (personal observation) and elsewhere as, for example, the Javanese Zebu of Papua New Guinea (Holmes, 1977). The existence of these fertile crosses is sufficient to make it possible to anticipate that the hybrid-bull infertility problem will be overcome through the production of back-crosses. After arriving at approximately the most desirable proportion of the parent types, selection will be commenced on reproduction, growth (over at least one dry season) and temperament.

Consideration of the use of Bali-cross cattle in monsoon Australia will be justified particularly where production is severely limited by poor pasture quality and environmental stresses, and where there are low fertility-levels or excessive weight losses in lactating cows.

There is now a greater awareness in Australia of commercial cattle-production of Bali and Bali-cross cattle and of research in other countries, and there has been a reciprocal interest in the Australian work and its possible application. Common interests include a need for the better definition of the current productivity of Bali and Bali-cross cattle, their productivity compared to local zebu cattle and the future potential of the Bali, the Bali-crossbreds, and the part they can play in crossbreeding systems. Coordinated work should, therefore, continue with research on and development of this species of cattle so valuable and peculiar to this region of the world. ■

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Chilling and freezing of meat in developing countries

C.L. Cutting

The World Animal Review justifiably concentrates on primary production problems. But most animals are bred and fed largely for slaughter and eating, and *post mortem* treatment greatly influences their palatability as food.

Refrigeration is the principal means employed for preserving quality prior to consumption, either through chilling to facilitate distribution, or freezing for long-term storage.

These processes are as important for the meat economy of developing countries as they are in temperate regions, although all procedures may not suit local needs.

However, unless carefully applied, refrigeration can damage eating quality. The details of the process are, therefore, highly important. Biochemical and engineering data on the thermal behaviour of meat carcasses are scattered about the world literature and have not, until recently, been very precise. Engineers usually assume that the fastest process is necessarily the best and also tend to over-estimate the effectiveness of their equipment. However, it is now becoming possible to define processes realistically and to establish regimes that maximize eating quality. This article attempts to summarize the current state of knowledge, first on the principles involved, and second, on the quantitative data now available, some of it still unpublished.

Measuring the temperature of pig meat with an electronic probe thermometer.

More detailed information is given in "Refrigeration techniques in developing countries" (International Institute of Refrigeration, 1976).

Dr Cutting is Project Adviser — TF/CUB 2(SWE), Meat Industry Development Institute, c/o FAO, Calle F. No. 205 e/9 y Linea, Vedado, Havana, Cuba. The author was formerly Head of the Processing and Distribution Division of the Meat Research Institute, Langford, Bristol, UK. The author wishes to thank numerous colleagues for their assistance in the preparation of this article, and Mr C. Bailey and the Institute of Refrigeration for permission to reproduce data given in Figure 1.

The principles

When meat is kept under ordinary atmospheric conditions, sooner or later it putrefies. This is the result of the proliferation of the spoilage micro-organisms naturally in or on the animal, which are spread over the surfaces after slaughter and dressing to an extent that depends on the care taken in regard to hygiene. "Bone-taint" can also occur deep down in the flesh.

Effect of temperature. Whatever the degree of initial contamination, the rate of microbial multiplication by cell division depends primarily on temperature.

It is standard practice to refrigerate meat to extend its storage life. Table 1, which is based on numerous published and unpublished experimental results, shows the importance of thorough chilling to around 0°C for maximum effect. Another reason for it is that food poisoning organisms cannot multiply below about 7°C.

At —1°C meat keeps slightly longer still, but below this it begins to freeze, which can be inconvenient and marginally damaging unless deliberately planned. Micro-organisms can still multiply in frozen meat, but at a reducing rate as temperature is lowered, until at about —8°C activity is suspended.

The maximum safe temperature at which frozen meat can be held is, therefore, about —10°C, although enzymic and physical changes still take place at a rate that can be reduced by further lowering of temperature.

Effect of relative humidity. Spoilage is faster the higher the relative humidity (r.h.) of the ambient air which, in commercial practice, is below 100 percent saturation, so that storage life is normally greater than shown in Ta-

ble 1, and some evaporation occurs. Quantitative data are sketchy, but at 2°C the storage life is doubled when r.h. decreases from 100 percent to 85 percent. The effect of decreasing r.h. is reduced when the temperature is increased.

Effect of air movement. Air currents also favour evaporation of surface moisture, inhibiting bacteria, but reducing yield. Severe dehydration discolours meat, with consequent trimming losses. This applies equally to frozen meat.

TABLE 1. **Effect of temperature and contamination on time before meat spoils at 100% r.h.**
(Days to spoilage)

Initial number [1] of bacteria/cm²	Temperature (°C)				
	0	5	10	15	20
100-10 000	11	8	3	2	2
10 000-1 million	6	4	2	1	1

Source: Meat Research Institute.
[1] 100-10 000 bacteria/cm² = excellent hygiene; 10 000 - 1 million = typical commercial range.

Important aspects of refrigeration
For both chilling and freezing the initial cooling operation may be differentiated from subsequent storage and transport. In addition, frozen meat usually has to be thawed ("defrosted") before use. There are, therefore, five distinct operations to consider for the time, loss of weight and quality involved.

Meats from different animal species vary somewhat in behaviour. Size (thickness) and fatness of carcass are important, as is the question of whether it is cut up into portions or wrapped in some way. A considerable amount of technical data has been published, but it is uneven and scattered. Current opinions and practice have been reviewed at symposia organized by the United Kingdom Meat Research Institute (1972; 1974).

Choice between chilling and freezing. In hot climates refrigeration is especially necessary, but the difficulty and cost of equipping a "cold chain" is greater than elsewhere. In any circumstances it is desirable first to chill meat, even if subsequently it is to be frozen or otherwise processed.

Although a large town can be supplied with meat from a distance by transporting the live animals, there will be considerable losses of weight, and even deaths, en route. It may, therefore, be preferable to slaughter animals near the feeding area and transport the meat chilled in refrigerated rail or road vehicles. Depending on how it is used, meat can be deboned, cut or jointed and transported in standard cardboard cartons. These can be stacked compactly with saving in space used and weight transported, compared with hanging carcass meat. With suitable precautions, hot meat can be deboned. It is essential to chill thoroughly before stacking, otherwise cooling is too slow.

Although frozen meat keeps longer than chilled meat, its production and distribution demand more costly equipment. But it can overcome problems of distance, distribution and seasonal fluctuation in supply. In a dry season fodder is lacking and cattle lose weight and may even perish. It is preferable to slaughter and freeze before this happens, cold store for some months and then transport frozen meat for local thawing. Again it is more convenient and economic to debone, pack and freeze in cartons.

Thawing is a lengthy process, requiring control, organization and expenditure on equipment and energy.

Refrigeration should be used primarily to solve the problems of supply and distribution of a country. Unnecessary refinements should be dispensed with. Refrigerated or insulated vehicles and display cabinets are not essential for urban distribution if sales are rapid. Consumer packs of quick-frozen foods and pre-cooked dishes may be less suitable for a developing country than bulk packs for catering. More recently, millions of people in the competitive, consumer-oriented economies have been persuaded to buy cabinets for storing quick-frozen food — this would be an unwanted development in countries where even domestic refrigerators are scarce.

Plant specifications. A meat refrigeration plant must be able to cool a specified number of carcasses or pieces of meat of a given average weight through a stated temperature range in a certain time. The temperature is usually taken in the centre of the thickest part of the hind leg, which is slowest to cool. "Average" temperature is more difficult to estimate. The following examples are taken from commercial refrigeration plants for beef to illustrate the type of performance needed:

- To cool 100-kg sides from 37°C to 14-10°C in 4 hours and then to —1°C in less than a further 16 hours;
- To cool 136-kg sides from 37°C to 4°C in 16 hours and then, as quarters, to approximately —18°C in 18-20 hours;
- To cool and freeze 50-kg quarters from 37°C to —10°C in 16 hours.

To comply with such specifications a refrigeration engineer must provide a plant calculated to fulfil two distinct requirements. First, the cooling unit must transmit cooling capacity to the air in the cold room *sufficient to absorb the heat in the meat, plus* leakage through insulation, air infiltration, fan heat, lighting, and body heat of cold store workers. This involves only the normal refrigeration expertise of calculating cooling-pipe surface-area, temperature difference between surface and air, evaporating temperature of refrigerant and air velocity through the cooler. Although there is some direct evaporative cooling as the meat dries, the water vapour is condensed again on the cooling pipes, thus releasing an identical quantity of heat (neglecting the latent heat of freezing this deposit).

Second, the cold air must succeed in *extracting the heat from the meat in the specified time*, by a suitable combination or cycle of air temperature and velocity while, at the same time, minimizing the evaporative loss of water from the meat. Refrigeration engineers generally know less about this aspect and specifications for cooling rates tend to be over-optimistic. This, however, may not be noticed

with the test methods and instruments often employed. Apart from the question of contractual liability, it may not matter if chilling is not as rapid as is claimed.

Effect of cooling rate on quality

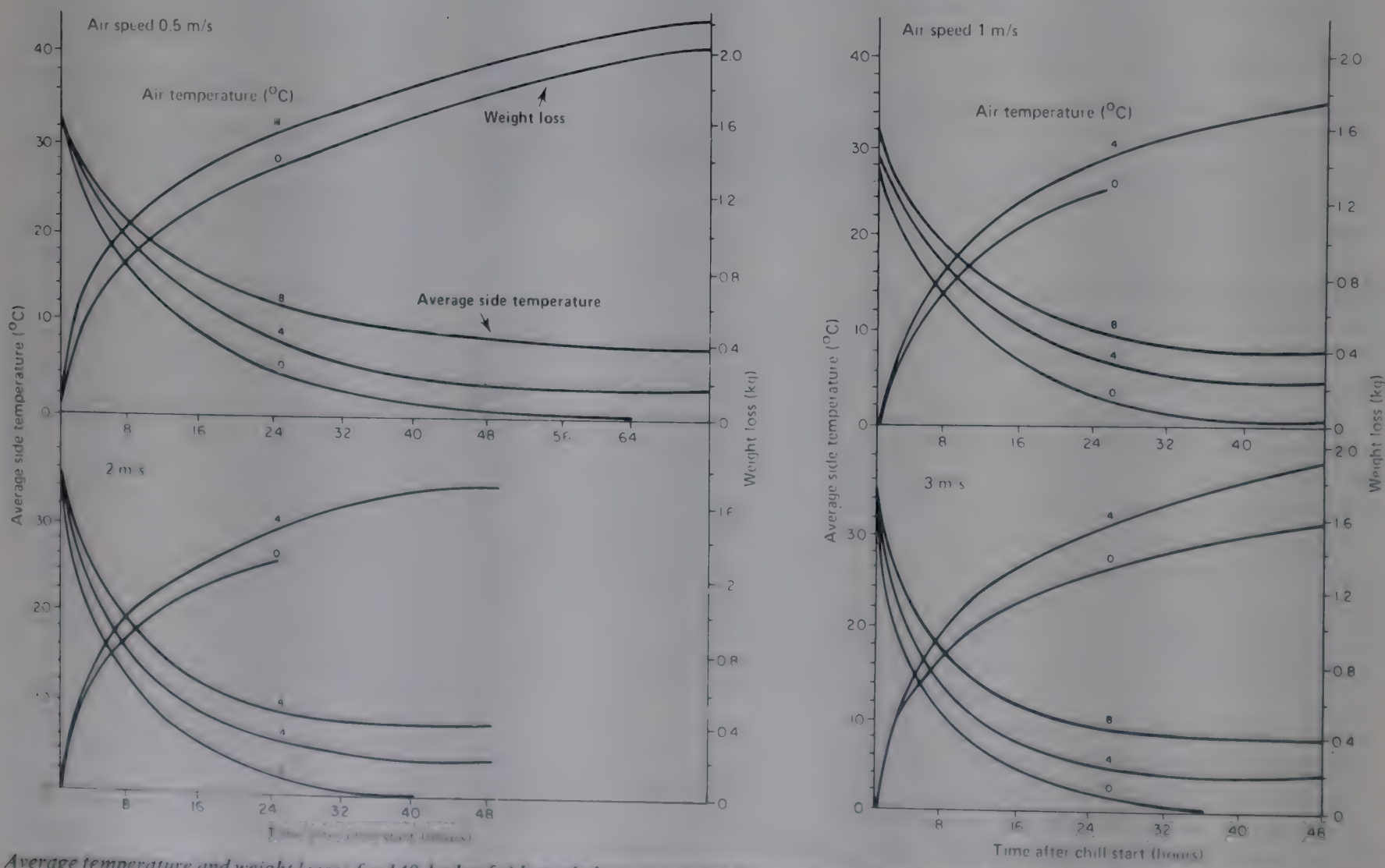
"Cold-shortening". It used to be thought in simple terms that the faster a refrigeration process was carried out the better, particularly as this generally lessens evaporative weight losses. It is now realized that rapid chilling may damage eating quality.

Within limits, reasonably fast cooling is conducive to microbiological quality and also reduces evaporation and drip loss on cutting up. However, it is now established that carcasses of beef and lamb (but not, apparently, pork), quickly cooled too soon after slaughter, suffer "cold-shortening" which results in disagreeable toughness when the meat is cooked. Subsequent "ageing" has no significant counteracting effect. In practical terms, any part of the carcass that falls below 10°C within 10 hours of slaughter is liable to toughen.

If hot beef carcasses are exposed to air at below about 6° to 8°C during the first few hours, the muscles near the surface cold-shorten. Calves and lambs, being small, cool so quickly that the entire carcass can easily cold-shorten, so that it is wiser to defer refrigeration for several hours. For New Zealand's export of lamb, processes have been developed to obviate cold-shortening by keeping the carcasses at an elevated temperature prior to cooling and by administering electric shocks to carcasses in order to accelerate *post mortem* biochemical changes. Retarded or delayed cooling lengthens the process and, therefore, utilizes more equipment, as well as increasing evaporative loss. Hot, deboned meat requires controlled two-stage cooling, first to 10°C over the first 10-12 hours, and later to 0°C. Although these delays introduce no microbiological hazard, the New Zealand "conditioning" process necessitates exceptionally good hygiene. Depending on food preferences a degree of toughness is not necessarily a critical factor. This needs assessment by food technologists and caterers before commitment on plant.

"Thaw-rigor". If meat is frozen before it goes into *rigor mortis*, the muscular contraction occurs catastrophically on thawing and produces excessive toughness and leakage of juice ("drip"). Existing ways of avoiding this defect are inconvenient. In Cuba recently 19 out of 20 tasters objected strongly to beef frozen whilst warm, comparable with the last example given above which combines cold-shortening with thaw-rigor.

Temperature standards. Unconnected with the above considerations, temperature values are laid down in various international regulations for meat handling, notably by the Common Market (European Economic Community, 1969) and the United Nations Economic Commission for Europe (1971). Committees of the FAO/WHO Codex Alimentarius are also drafting related standards for governments to consider.



Average temperature and weight losses for 140-kg beef side cooled to any required temperature in moving air, and 94 percent r.h. (Cox and Bailey, 1977).

A maximum of 7°C is prescribed for boning, transport and storage of fresh meat, presumably to prevent multiplication of the food poisoning salmonella micro-organisms.

Various other temperature levels apply to frozen meat.

Quantitative practical data

Chilling of carcasses. The figure reproduces recent Meat Research Institute (United Kingdom) data showing the influence of air temperature and air speed on the cooling time and weight losses of beef carcasses (Cox and Bailey, 1977).

Post mortem biochemical reactions release heat equivalent to a 4°C increase in carcass temperature and consequently, for several hours after slaughter, the temperature in the thickest part of a beef carcass in a chill room actually rises instead of falling.

The heat load of a hot carcass is nearly four times the average over the first 24 hours but, for a group of carcasses, this peak is spread out, depending on the time taken to load the chill room. If this takes eight hours, the peak heat load is only twice the average. In practice, therefore, air temperature usually rises during loading and takes some hours to fall again. This cycle is beneficial in reducing risk of cold-shortening.

There is no advantage in air speeds above 0.5 to 1 m/s, because weight loss is not apparently reduced and the additional fan heat has to be extracted by the refrigeration system. For example, increasing from 0.5 to 3 m/s at 0°C for a 24-hour cooling cycle, taking two hours to load, doubles the peak heat-load but only speeds meat cooling by 10 percent.

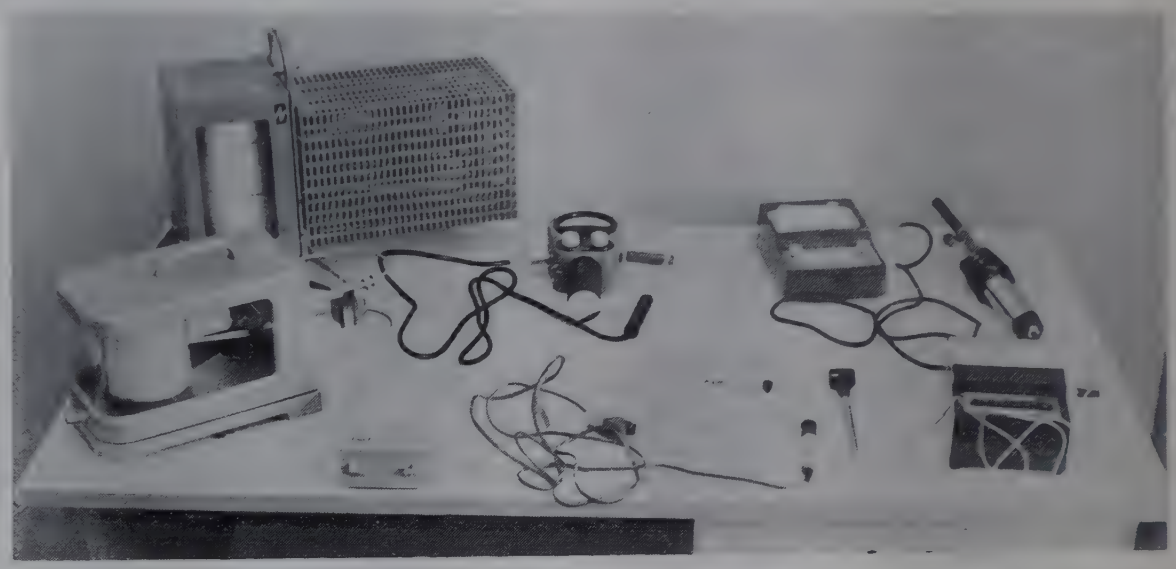
Similar data have been published for lambs (Earle and Fleming, 1967) and for pigs (Cooper, 1968; Tamm, 1973).

Commercial data. In commercial practice, air temperature fluctuates and air movement is uneven. Ventilation, normally expressed as "air changes per hour", needs conversion into average linear velocity over the meat in order to compare with experimental

TABLE 2. **Cooling times of carcasses in commercial EEC chillrooms**
(Hours to reach given temperature)

Product		Temperature (°C) Thickest part of leg				Surface of leg		
		15	10	7	4	10	7	4
Beef (56 sides)	Average	23	31	39	45	12	17	19
	Maximum	48	53	60	—	40	64	—
	Minimum	13	19	27	31	4	12	15
Pork (42 sides)	Average	12	15	17	21	8	11	14
	Maximum	18	19	28	35	17	24	24
	Minimum	8	12	14	16	2	4	7
Lamb (12 sides)	Average	12	18	20	24	7	14	17
	Maximum	18	24	28	35	10	24	—
	Minimum	8	12	14	16	—	6	—

Source: R. Malton, unpublished results of Meat Research Institute.



Some instruments used for investigating meat refrigeration at the Meat Industry Development Institute, Havana. From left to right, back row: thermophygrograph; hot wire anemometer (for air velocity); electronic psychrometer (for relative humidity). Front row: thermograph; miniature thermograph; electronic probe thermometer; miniature vane anemometer.

Beef quarters in a commercial chillroom.

TABLE 3. **Freezing of the hind quarter of a 190-kg beef carcass**

Air temperature (°C)	Air speed (m/s)	Hours from 2°-6° to —15° at centre	Weight loss (Percentage)
—20	2	24	0.29
—20	4.5	21	0.31
—20	11.4	20	0.18
—35	0.25	21	0.36
—35	2	15.5	0.33
—34	4.5	12	0.22
—56	2	8.5	0.22
—57	4.5	9	0.13

Source: Lorentzen and Røsvik (1959).

data. It is instructive to investigate performance by measuring temperature, r.h., air speed and weight loss in commercial operations. Table 2 shows the results of such a survey in some EEC countries. There is a wide variation in cooling time, but the quickest processes for beef and lamb incur the risk of cold-shortening toughness in the outer layers of the carcass.

In a number of cases beef lost 1.4 ± 0.3 percent during chilling and pigs 1.5 ± 0.5 percent, depending on weight and cooling schedule. It is claimed that commercial ultra-rapid cooling can reduce the loss of weight of pigs to about 1 percent.

Chill storage. Meat keeps longest at just below 0°C in air at about 90 percent r.h. circulated at about 0.05 m/s. Beef can keep for three weeks, or even longer with exceptional hygiene; veal for one to two weeks, lamb for 10-15 days and pork for one to two weeks (International Institute of Refrigeration, 1967).

An atmosphere with 10 percent of carbon dioxide retards microbial activity and chilled meat then keeps for up to nine weeks, depending on cleanliness. This permitted the former trade in chilled carcass beef between Australia and Europe in specially equipped ships. If jointed or deboned meat is vacuum packed in an airtight, flexible film-envelope, it generates its own atmosphere of carbon dioxide. This lengthens storage life at 0°C to nine ± two weeks if it is properly processed, well sealed with no "pin-holes" and if the pH is under 5.8. After opening the pack the meat can be expected to keep for four to five days at about 5°C.

Although beef can be "tenderized" by hanging in chill for two or three weeks, this is an extravagant use of refrigerated storage space. The tenderizing is practically finished in six days and occurs faster the higher the temperature. In fact, meat can be cut up and sold after 24 hours chilling and, if distributed rapidly, close temperature control is unnecessary. For wide distribution, transport conditions need attention (International Institute of Refrigeration, 1974).

Freezing of meat. Contrary to popular belief it is doubtful whether rapid freezing in an hour or so significantly improves eating quality or reduces "drip" loss. In any case it is physically impossible to freeze carcasses or large joints really rapidly as shown by Table 3. It takes 20-24 hours for a beef hindquarter to be chilled down from 2-6°C to —15°C with an air temperature of —20°C. Lowering the air temperature reduces the freezing time but, for practical purposes, —40°C may be considered as the lowest temperature to use. Air velocities above 2 m/s reduce the freezing time but are nevertheless uneconomic. Recommendations for acceptable commercial freezing-practice for carcasses (FAO/WHO, 1969) are summarized in Table 4.

Cuts, joints and offal can be frozen in a cold-air blast in an hour or two depending on thickness. Packages can be immersed directly in some cooled fluid. Regularly shaped packets, including consumer packs, plate-freeze conveniently.

It should be pointed out that freezing is also used to destroy parasites of *Cysticercus bovis* (—10°C for two weeks) and *Trichinella* (—15°C for 30 days) in meat carcasses.

TABLE 4. **Main provisions of Codex Alimentarius draft standard for freezing**

Product	FREEZING	STORAGE	
	Initially 15°C reduce to —8°C in: (Hours)	Initially —10°C reduce to —15°C in 15 hours Temperature (°C)	Maximum period (Months)
Beef (and veal)	80	—14	9
Mutton and lamb	48		
Pork	60	—18	
Meat in cartons	48		
	Transport	—10	

Source: FAO/WHO (1969).

Frozen storage. The lower the temperature, the longer frozen meat keeps (Table 5), but for practical purposes —18°C (0°F) may be considered adequate.

Conditions have been recommended for transport of frozen meat (International Institute of Refrigeration, 1974), which must be rapidly transferred to and from cold store so as to minimize exposure to ambient temperature.

Evaporative loss of frozen meat is smaller the lower the storage temperature. In industrial air-cooled stores

the approximate loss per four weeks of unwrapped meat has been found to be as follows:

Temperature (°C)	Loss (%)
—30	0.2
—25	0.3
—20	0.4
—18	0.5
—12	0.7
—10	0.85
— 8	1.05

Loss is greater in partly empty stores than in full ones. It can be prevented by dipping meat in, or spraying it with, cold water so as to coat it with ice (glazing).

Cartoned meat loses about half as much by sublimation and condensation as frost inside the carton as does uncartoned meat. In polyethylene wrapping the loss is from 0.05 percent per four weeks at —30°C to 0.16 percent at —8°C. In pipe-cooled stores losses were much smaller. Small coolers with high air flow rate and high temperature-differential increase drying losses.

If the temperature of a store rises above —8°C for any considerable period, e.g., during a plant breakdown, various moulds can develop including "black spot", which is troublesome to eradicate.

Thawing frozen meat. Thawing is more difficult and a slower process than freezing because the partly thawed outer-layer does not conduct heat as well as frozen material does, and because micro-organisms multiply quickly if the surface gets warm.

Although water can be used for thawing in some cases, air thawing is usually best. It takes several days for a frozen quarter of beef to thaw naturally in the atmosphere and large-scale operations necessitate fans and coolers to control conditions. The optimum air-temperature is about 10°C at a speed of 0.5 to 1 m/s over the meat.

TABLE 5. **Storage life of frozen carcass meat**
(Months)

Product	Storage temperature (°C)				
	—12	—15	—18	—25	—30
Beef	5-8	6-9	8-12	18	24
Lamb and veal	3-6	—	9	12	24
Pork	2	—	4-6	8-10	12-15
Bacon (green, unsmoked)	—	—	2-4	6	12
Edible offal	—	—	4	—	—

Source: International Institute of Refrigeration (1964-1972).

Conclusion

Meat is a very variable commodity. The above figures should only be taken as an approximate guide (within ± 20 percent) to the behaviour that may be expected. Nevertheless, there is now a sound basis compatible with ordinary engineering tolerance, for planning realistic production-schedules with refrigerated meat. ■

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Prospects for processing and marketing cassava products as animal feed

T.P. Phillips

Cassava (tapioca, manioc, yuca, mandioca), globally the most important of the tropical root crops in developing countries, has over the last 15 years become an important energy feed ingredient for the compound feed manufacturers of the European Economic Community (EEC). The importance of cassava as an animal feed ingredient results from the EEC Common Agricultural Policy. This provides for the alteration of world market-price relativities between energy and protein-rich ingredients, making it economically "attractive for European compounders to use large quantities of relatively cheap protein and energy sources (viz., soybean meal and cassava respectively), rather than cereals, in the production of compound feeds. In short, a product of superior quality to cereal is fabricated from an appropriate mix of soybeans and cassava". (Phillips, 1974).

Taking fermented cassava from chamber (Photo: N. McKee, IDRC)

The demand for cassava has grown from 0.4 million tons in the early 1960s to probably 4 million tons in 1978 (see Table 1). In the early 1960s the product was cassava flour shipped in gunny bags while today the product is cassava pellets — these are shipped in bulk on chartered ships with capacities of some 85 000 tons. While many countries supplied cassava in the early years, the market is now dominanted by Thailand, which supplies over 90 percent, and Indonesia, which supplies the remainder. There are indications that the EEC demand for cassava will continue to grow, and the author estimates that the demand will reach 6 million tons by 1985.

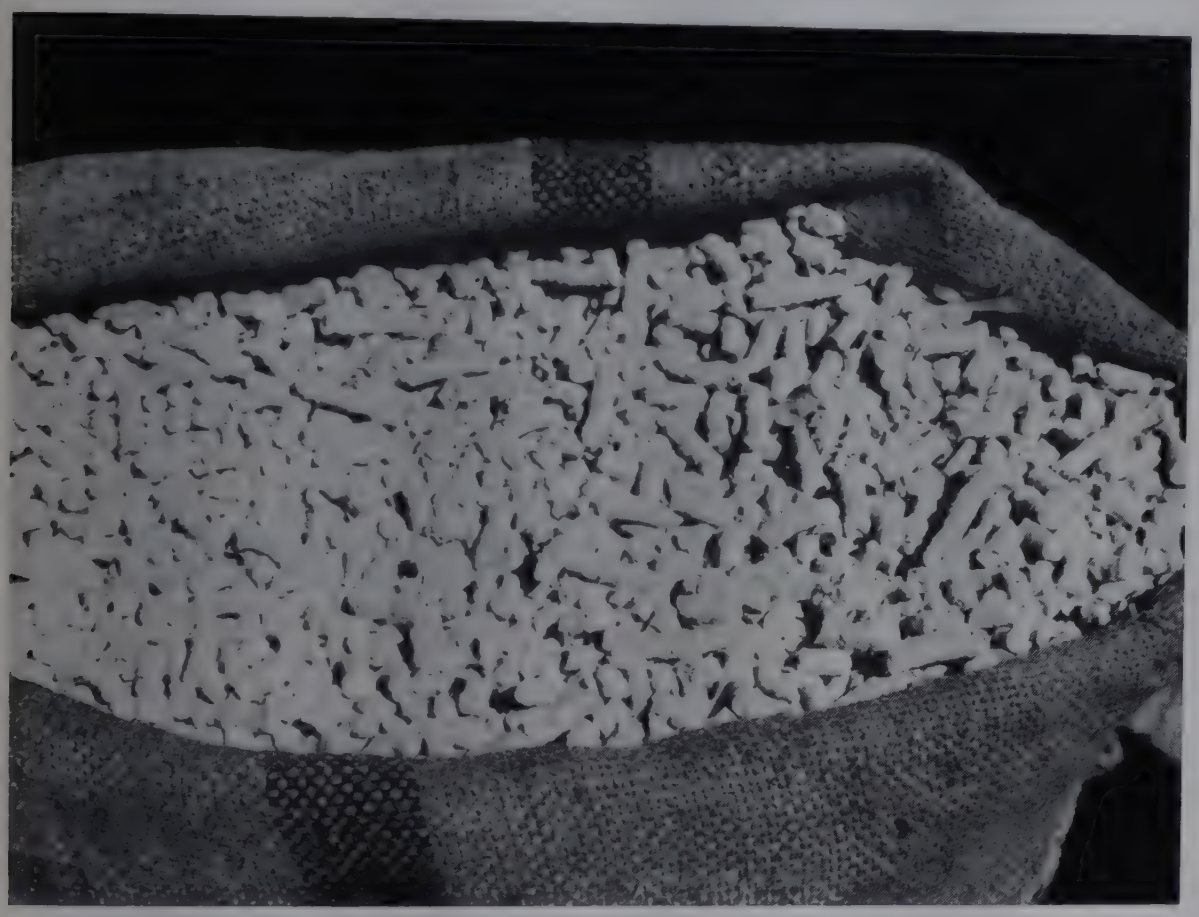
This estimate may be optimistic, given some of the concern expressed over the growing importation of cassava into the EEC. At the base of this concern is the possible effect of such importation on the national feed grain industry, owing to the fact that cassava enters the EEC with only minimal tariffs. The resulting consideration then is whether or not cassava should be subject to a levy system similar to that applied to feed grains. Such a levy would make it less economical for feed manufacturers to use cassava unless cassava suppliers can lower prices sufficiently to offset the levy. Attempts to increase the price of cassava are likely to meet with resistance from UNCTAD and GATT

The author is Associate Professor, School of Agriculture Economics and Extension Education, University of Guelph, Guelph, Ontario N1G 2W1, Canada

(UNCTAD = United Nations Conference on Trade and Development; GATT = General Agreement on Tariffs and Trade), and presumably also from compound-feed manufacturers in those EEC countries that are large users of cassava. Be that as it may, it is probably fair to speculate that all these considerations will have the effect of reducing the rate of increase in the use of cassava. This has implications for countries hoping to enter the EEC market. They must realize that, because the market may not expand as rapidly in the future as it has in the past, they may face stiffer competition from the two established exporters, Thailand and Indonesia. Furthermore, potential cassava-exporters must also realize that to effectively enter the EEC market it is necessary to be able to export a minimum of 100 000 tons of pellets per year (GATT, 1977). The author feels that, in some instances, the minimal annual shipments may have to be as much as 240 000 tons of pellets.

Thus entry into the EEC market is not easy, although the rewards may be great. Both Thailand and Indonesia have reaped the obvious benefits of exporting the crop, namely the generation of foreign capital, running annually at US $333 million and US $24 million respectively.

Both countries have also demonstrated that production and manufacture of cassava chips (the first steps in the production of pellets) can be done on a small scale. In Thailand, for instance, the average area of cassava planting is 3.3 hectares, and each "chip" plant services, on average, 100 to 400 hectares per year. The development, therefore, of a cassava export industry can have thee ffect of providing small farmers with a cash crop as well as resulting in a rural-based, small-scale processing industry. The eventual production of pellets tends to be done in large-scale pellet-plants, many with a capacity of over 100 000 tons a year. In part this is because large-scale processing tends to be synonymous with better management and better quality control.



Cassava pellets from Thailand (Photo: B. Nestel, IDRC)

However, as previously noted, the EEC market may not be so promising for new entrants. At present, the only other developed market for cassava as an animal feed is Japan, but it is likely that the Japanese will attempt to fulfill their needs from the cassava supplies available in Southeast Asia.

Perhaps the real future market for cassava as an animal feed is in the cassava-producing countries themselves. There are three methods by which cassava can be used as an animal feed in tropical countries:

- As an ingredient in compound feed manufacturing;
- As a substrate for single cell protein production;
- As a "feed extender" during periods of feed shortage.

The following sections contain a discussion of these three aspects of

TABLE 1. **EEC imports of cassava, 1962-1977**
(Thousand tons)

Country	1962	1963	1964	1965	1966	1967	1968	1969	1970	[1] 1971	1972	[1] 1973	[2] 1974	[3] 1975	[3] 1976	[3] 1977
Germany, Fed. Rep.	336	387	462	520	702	533	481	548	591	479	387	420	431	484	—	—
France	23	20	18	17	16	—	—	—	—	38	139	159	164	146	—	—
Netherlands	1	5	17	76	96	159	237	444	502	599	650	700	1 088	1 233	—	—
Belgium-Luxembourg	23	72	105	100	70	113	127	212	268	278	293	204	394	449	—	—
Other	30	0	0	1	1	0	—	—	49	356	381	417	—	—	—	—
Total EEC	413	484	602	714	884	[4] 805	[4] 845	[4] 1 204	[4] 1 410	1 750	1 850	1 900	[4] 2 077	[4] 2 312	[4] 3 441	[4] 3 700

Source: Phillips, 1974.

[1] EEC6 expanded to EEC9. The three additional countries did not use cassava prior to entry into the EEC. — [2] Figure from GATT, 1977. — [3] Figure from Bangkok Bank, 1977. — [4] Total EEC imports exceeded these values.

cassava as an animal feed in tropical countries.

Compound feed. For any commercial operation the ingredients of compound feed are selected in such a manner as to minimize the total cost of the feed while meeting specified nutrient (protein, energy, calcium, etc.) and quality requirements. Linear programming (LP) is used to determine which ingredients to include in the ration and the competitiveness or complementarity of various crops.

In the EEC the general specifications for cassava are: minimum starch content 62 percent; maximum fibre content, 5 percent; maximum sand content, 3 percent; and maximum moisture content, 14 percent (FATT, 1977). Given cassava of this composition and an assumed protein content of 1.6 percent it is possible to illustrate relationships between the potential percentage of cassava and other products in the rations and the price of cassava (see Table 2). At the time the rations were determined the price of cassava to the feed compounder was approximately US$ 160/ton.

The results suggest that an increase of US $5 per ton would result in the removal of cassava from cattle rations and a sharp decline in the proportion of cassava in pig rations. Conversely, a decrease in price would appear to lead to an increase in the use of cassava but, because most feed compounders place an upper limit on the amount of cassava in the ration (which is lower than the amounts indicated in Table 2), a price decrease implies a reduction in revenue to the sellers of cassava. It is, therefore, not surprising to find cassava priced at a level that provides the greatest returns to its sellers while still being competitive with other ingredients. The figures in Table 2 also illustrate that cassava competes with cereals and cereal by-products and complements oilseeds and oilseed cakes. It other words, cereal product percentages increase when cassava percentages decrease, while the percentages of oilseed products move in the same direction as the cassava percentages.

TABLE 2. **Average percentage composition of typical Dutch feed rations**

Ingredients	Cassava price (US$/ton to feed compounder)							
	140	145	150	155	160	165	170	175
Cattle feed								
Cassava	25.6	25.6	25.6	17.4	13.0	—	—	—
Cereals	—	—	—	—	—	17.9	17.9	17.9
Cereal by-products	5	5	5	19.3	28.9	24.9	24.9	24.9
Oilseed and cake	29.4	29.4	29.4	23.9	19.7	16.8	16.8	16.8
Animal meal	5.7	5.7	5.7	5.7	6.5	6.5	6.5	6.5
Other	34.3	34.3	34.3	33.7	31.9	33.9	33.9	33.9
Pig feed								
Cassava	43.8	38.4	38.4	38.4	31.7	18.4	14.5	9.0
Cereals	5	5	5	5	5	21.5	26.1	33.5
Cereal by-products	7.5	7.5	7.5	7.5	17.9	12.2	10.6	7.9
Oilseed and cake	25.7	22.4	22.4	22.4	17.8	15.2	15.0	15.0
Animal meal	6.4	8.4	8.4	8.4	8.9	8.9	8.9	8.7
Other	11.6	18.2	18.2	18.2	18.7	23.8	24.9	25.9
Poultry feed								
Cassava	10.5	10.5	9.1	3.4	—	—	—	—
Cereals	46.6	46.6	49.3	54.8	57.8	57.8	57.8	57.8
Cereal by-products	7.2	7.2	5.8	6.3	6.7	6.7	6.7	6.7
Oilseed and cake	22.5	22.5	22.4	20.9	19.7	19.7	19.7	19.7
Animal meal	5.2	5.2	5.2	5.0	6.0	6.0	6.0	6.0
Other	8.0	8.0	8.2	9.6	9.8	9.8	9.8	9.8

Swine experiment with cassava diet (Photo: N. McKee, IDRC)

The results are applicable to any developing country provided that the same nutrient standards are used and that the ratios of the price of other feed ingredients to the price of cassava are the same. Some of the more important ratios are as follows:

Ingredient	Price ratio
Sorghum	1.16:1
Barley or maize	1.19:1
Wheat	1.22:1
Sunflower meal	1.38:1
Soybean meal	1.64:1

If either or both of the above conditions do not apply to a particular country the percentage of cassava in the ration that is economically optimal will differ from the amounts indicated in Table 2. Nevertheless, the implication of Table 2 is that it is economically sound to include cassava in compound feed rations.

Cattle-feeding trials at the University of Viçosa in Brazil, in which cassava chips supplemented with urea and cottonseed meal replaced ground maize, further indicate the economic advantage of using cassava in feed rations. The results showed that, while daily weight-gain and feed-intake decreased as the percentage of cassava in the ration increased, feed efficiency (kg feed/kg gain) improved. These findings, when combined with information on the price of feed ingredients,

Cassava-chipping machinery near Khon Kaen, Thailand (Photo: C. Sanger, IDRC)

indicate that the cost of achieving a 122-kg gain (the base cost) is reduced as the percentage of cassava in the ration increases (see Table 3). However, to complete the economic analysis it is necessary to discount the savings in feed costs by the additional cost incurred through a longer feeding period or a lower total weight-gain for a fixed time-period. These additional costs tend to vary between regions and production systems and are, therefore, not analysed in this article.

Clearly cassava has a future as an animal-feed ingredient in tropical countries. But this future is inhibited by the underdevelopment of the compound-feed industry in most developing countries, which, in turn, reflects the relative lack of intensive livestock-production. However, if and when intensive livestock-production becomes more common, it will generate a demand for compound feed which, in turn, could generate a demand for cassava and other indigenous crops. This latter demand may eventually encourage farmers to produce for the emerging domestic market.

Development of an indigenous compound-feed industry may, of course, require the establishment of rural processing-plants (in the case of cassava, this may mean chipping and drying plants) and provision of infrastructure that will allow the ingredients to be shipped to the compounding plant. These additional requirements, however, would appear to be beneficial in many countries.

TABLE 3. **Cost of cattle ration with ground maize replaced by cassava chips and cottonseed meal**

Ration [1]	I	II	III	IV	V
Daily weight gain (kg/day) *A*	1.16	1.13	1.05	1.01	.85
Daily consumption (kg/day) *B*	10.20	9.30	8.59	8.16	6.95
Feed efficiency (*B*/*A*)	8.79	8.23	8.18	8.08	8.18
Increase in number of days required to gain 122 kg	—	3	11	16	39
Total consumption to gain 122 kg	1 071	1 004	996	987	993
Price of ration without supplement (US$/kg)	.18	.16	.15	.14	.13
Feed cost for gain of 122 kg (US$)	192.78	160.64	149.40	138.18	129.09

Source: Castro, Coleho da Silva and Barbosa (1975). Calculation and prices are by the author.

[1] Composition of ration (all rations contain 2 percent vitamin supplement):

Ration	Ground maize	Cassava	Cottonseed	Urea
I	88.50	0	7.80	1.70
II	66.38	20.50	9.17	1.95
III	44.25	41.00	10.55	2.20
IV	22.13	61.50	11.92	2.45
V	0	82.00	13.30	2.70

Production of single-cell protein. Research workers (Gregory *et al.*, 1976 and Hutagalung and Tan 1976) have demonstrated that cassava can be used as a substrate for the production of single-cell protein. The work of Gregory has reached the point where a 3 000 litre fermentor, producing a 28 to 38 percent protein biomass, has been developed and installed at the Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. Tests are now under way to determine the suitability of the resulting feed for pigs. Preliminary indications are that this process is capable of producing a nearly balanced pig-feed directly from cassava. It also means that many more pigs can be supported per unit land area by the processed feed than by conventional feeding practices.

It will undoubtedly be a few years before the cassava-based single-cell protein plant will be used by farmers in developing countries, but this system allows developing countries to greatly increase livestock-production without making great demands on the land base — which, in some developing countries, is a serious constraint.

Feed extender. In the near future the most important role for cassava as animal feed may be as a "feed extender". For purposes of this article a "feed extender" is defined as a supplementary feed that is used only when there is a shortage of "normal" feed, such as grazing. A feed extender is not primarily intended to be a balanced ration in itself.[1] Rather, it should be used to maintain the weight gain achieved during the flush season. A case in point would be beef production in the drought-polygon area of Northeastern Brazil. In this region, grazing is the main source of feed but,

[1] Dr Gustavo Nores of CIAT notes, however, that there must be sufficient protein in the diet to enable the animals to use the energy in a feed such as cassava.

Spreading cassava chips for sun-drying near Khon Kaen, Thailand (Photo: C. Sanger, IDRC)

The pilot plant used to produce microbial protein using cassava roots as the energy source at the CIAT swine unit. (Photo: CIAT)

for three months of the year, there is virtually no feed for the cattle. As a result of weight losses during this latter period, it takes the cattle five years to reach slaughter weight. If, however, the cattle were fed cassava chips during the dry period,[2] they could probably reach market weight in 3 years. Although the use of cassava as a feed extender in animal production is considered feasible by researchers, no one as yet has done much research on estimating the exact amount and time of feeding that would be optimal.

Another use of cassava as an animal feed in the general area of feed extenders is in the production of cassava forages. Work currently underway in a number of Latin American countries indicates that the use of cassava forage is attractive for a number of reasons: high yield (31.86 tons of dry foliage, at 18.2 percent crude protein, over a 17-month period); ease of production in the quantity required; and relatively low cost (in Venezuela, cassava forage is 20 percent of the cost of alfalfa meal — Montaldo, 1977). The production of cassava forage represents a level of sophistication above the simple feeding of cassava roots to animals, but both forms of feed extension are very promising.

Conclusion. It is evident that cassava has an important role to play as an animal feed. This potential may not be realized if individual researchers and policy makers fail to promote the use of cassava and other indigenous crops as animal feeds. The failure to promote cassava represents a failure to increase the demand for a tropical crop, to develop a new rural industry, and to save foreign exchange.

At a time when the benefits of greater self-sufficiency are being appreciated it would seem prudent to examine the potential role of cassava as an animal feed in developing countries. ■

[2] There are reports that farmers in some regions of Brazil plant cassava sparsely in areas where cattle graze so that the cattle may eat the aerial part of cassava in the dry season. One variety of cassava reportedly can be kept in the ground for 7 years. There are also reports that some farmers in Northeastern Brazil are beginning to feed fresh cassava to dairy cows during dry periods.

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SHORT COMMUNICATION

Dairy cattle breeding in the humid tropics

An FAO Expert Consultation on Dairy Cattle Breeding in the Humid Tropics was held at the Haryana Agricultural University, Hissar, Haryana, India, from 12 to 17 February 1979. It was attended by 15 experts from 10 countries, a large number of observers from the host country, India, and representatives of the World Bank and FAO.

The objectives of the Consultation were to review existing knowledge and experience from cattle breeding experiments and development projects in the humid tropics; to recommend suitable guidelines for the establishment of national programmes and policies; to determine resource requirements for the implementation of these programmes and policies; and to discuss cooperative research for evaluating strains and breeding systems and suggest ways and means by which such research could be conducted.

The most suitable types of cattle. From the review of existing knowledge and experience it was concluded that, for a broad range of production systems in the humid tropics, the most suitable cow was one with a proportion of genes from adapted cattle of tropical origin and a proportion from productive cattle of temperate origin. This type of cow could be produced either by continuous crossbreeding or by crossbreeding followed by selection toward the formation of new synthetic breeds.

Recent efforts at new breed formation using *Bos taurus* and *Bos indicus* parents were discussed. These parents were the Jamaica Hope and the Australian Milking Zebu (AMZ). The AMZ is the younger of the two and is just entering its third generation of selection by progeny test.

It was pointed out that, in a very harsh environment in which a cross is to be made in order to improve highly adapted local breeds, the Jamaica Hope, which has high production already combined with some degree of adaptation, could be a better source of productivity than a temperate breed. Similarly, if the conditions of production were based on grazing (with no legumes in the pasture and little or no supplementary feeding), the AMZ might be the breed of choice.

Breeds such as the Jamaica Hope and the AMZ represent only a few of the possible starting points for new breed development. There is, therefore, considerable merit in exploring others on an experimental basis. It has to be recognized, however, that it takes two or three generations to establish ease of milk "let-down" in a population and, though in theory lactation-milk yield could be improved at about 2 percent per year, 1 percent is a more realistic figure. As most crossbreeds begin with yields of between 1 500 and 2 500 kg of milk, it would take at least 30 years of selection to reach the productivity of the Jamaica Hope at Bodles (Jamaica). What has already been done, therefore, offers opportunities of practical application while awaiting the results of further exploration along new lines.

Selection for new breed development. The starting point of selection for new breed development also received the Consultation's attention. It was recognized that, because of the slow rate of progress once selection had started, the higher the production of the foundation stock the better. It was also felt that since a mosaic of parental characters and not a blend was required in new breed development an F_2 would be the best starting point. In the F_1 there is a complete set of genes from each side of the cross while the best chance of segregation and recombination occurs in the F_2.

Where it is considered desirable to undertake a backcross it should be from a selected F_2. The F_2 demonstrates a wide variety of genotypes from a recombination of the parental genes. The mating of selected F_2 animals with a pure breed should thus provide a more suitable foundation for new breed development. It seems there is very little other reason for making a backcross. It would appear from experience and genetic theory that, in most cases, selection from within the F_2 should give the desired combination of traits for the formation of new breeds.

While most temperate breeds have shown good results in crosses with tropical breeds, it was recommended that future efforts be concentrated principally on the use of the Holstein (or Friesian) and the Jersey. The various systems in which these breeds can be used in conjunction with local

breeds were discussed. It was agreed that, whatever systems and breed combinations were adopted in a particular region or environment, the important question was how to maintain a high rate of genetic improvement after the first generation of crossing. Progeny testing and selection of bulls for widespread use in artificial insemination (AI) are the principal means by which genetic gains are made in developed populations. The establishment of such schemes in most local populations in the tropics is, however, at least in the short term, likely to be difficult for a number of reasons, including the absence of a milk recording system, small herd size, a low level of AI use, late age of cows at first calving, late age of bulls at first service and the possible obscuring of additive genetic differences between bulls by heterosis in crossbred progeny of varying grades.

Possible alternatives, therefore, involve taking advantage of the continuous genetic gain achieved in developed populations by the regular introduction of semen or by the development of a rotational crossbreeding system.

Nevertheless, where local conditions make it possible, progeny testing schemes are recommended. Methods of assessing the value of a genotype for selection and progeny testing require standardization. In the assessment of milk production, for example, records should include, in addition to lactation yield, data on milk composition, interval between calvings, age at first calf and differences in viability. These will enable average daily production over a lifetime to be assessed. A comprehensive list of traits to be documented was prepared and approved by the Consultation.

Resource requirements. On the subject of resource requirements, the Consultation concluded that, in developing breeding programmes an "entire farming systems" approach should be followed. This should help develop farming programmes that utilize all the available resources on the individual farm for optimum production and profit by appropriate adjustment of the dairy enterprise with crop production activities.

It was also pointed out that the success of any breeding programme would depend on the organization of a composite, integrated package to support the programme that should include organized milk marketing, incentive prices, institutional credit, insurance and other inputs and services.

In regard to breed, strain and breeding-system comparisons, the major requirements were identified as either cooperation with commercial and/or village producers for arranging comparisons in their herds, or model units emulating practical conditions such as the evaluation and demonstration modules for breeding comparisons under extensive systems at the "Centro Agronomico Tropical de Investigación y Enseñanza" (CATIE), Turrialba, Costa Rica, and the model farm units for comparison under intensive systems at the National Dairy Research Institute, Karnal, India.

In either case the following resources would be required:

(i) A supply of semen or breeding stock of the breeds to be tested with special veterinary arrangements being made for international shipments;
(ii) Sufficient holding facilities both for one-time comparisons and for long-term breeding systems including the maintenance of indigenous breeds or crossing systems for continuous evaluation;
(iii) An efficient and comprehensive recording system with data processing equipment (preferably a minicomputer) not only for the analyses of results, but also to assist in regular herd management;
(iv) A project management service to ensure careful adherence to specified husbandry practices, veterinary care and data collection procedures, as well as for providing promotional information.

For the one-time comparisons referred to in (ii) above, useful evaluations can be made with facilities for a minimum of 200 head per breed group in similar environments including several herds containing a few members of each group.

For long-term breeding system comparisons, rates of genetic improvement and inbreeding are involved, which require at least 2 000 breeding females and the progeny testing of not less than 8 males per year.

Further work. The Consultation identified a number of questions on which it was agreed further work was required. These included the following:

- The development of indices of overall merit which combine the main traits of economic consequence;
- The development of efficient recording systems for use under field conditions in order to utilize data from small farmer herds taking into consideration the limitations imposed by herd size and genetic variation;
- Development of designs for breeding trials and programmes that are efficient in statistical and economic terms;
- Clarification of the nature, magnitude and role of heterosis;
- Whether bull rankings in temperate conditions apply in (a) purebreeding and (b) crossbreeding under tropical conditions;
- Investigation of the biological causes of genetic differences between tropical and temperate breeds and their crosses, including studies on behaviour, chromosomes, physiology and disease resistance;
- The relationship between body size and efficiency under tropical conditions with respect to milk and meat production as well as draught capability;
- The choice of breed, where new breed or semen introduction is being planned.

Finally, the Consultation made a number of important recommendations addressed to the Director-General of FAO and to Member Nations on breeding methods and genetic resources management in the humid tropics. These will appear in the Report of the Consultation now in course of preparation. ■

Feed situation and short-term outlook [1]

In 1978/79 the feed supply situation was generally favourable for livestock producers. Grazing conditions improved (with the main exceptions of New Zealand and parts of Latin America) and roughage production, which still accounts for the largest part of total supplies of feed nutrients (*Utilization of grains in the livestock sector: trends, factors and development issues*. 1979. Rome, FAO. Document CCP:ME 79/6), increased in most parts of the world. World grain crops reached a record level (Figure 1) and output of oilcake and meals as well as cassava and other grain substitutes also rose. Nonetheless, in international markets, owing to relatively strong demand and supply management measures in the United States, prices of feed grains increased (Figure 2). Intervention prices of oilcakes, meals and cassava, supplies of which have been less ample, rose more than those of feed grains.

While it is not possible at this stage to estimate 1979/80 production of fodder and feed, the feed supply situation next year is not expected to remain as favourable to livestock producers as it was in 1978/79. The severe winter in the northern hemisphere resulted in a reduction of hay and silage supplies to fairly low levels. Cassava export availabilities are also expected to decline this year. Although early estimates indicate an increase in area sown in soybeans, planting intentions of farmers in the United States — the leading exporter of feeds — suggest a decline in the area under feed grains in 1979. The FAO early forecast made in

[1] As of 28 May 1979. **Source:** FAO Commodities and Trade Division.

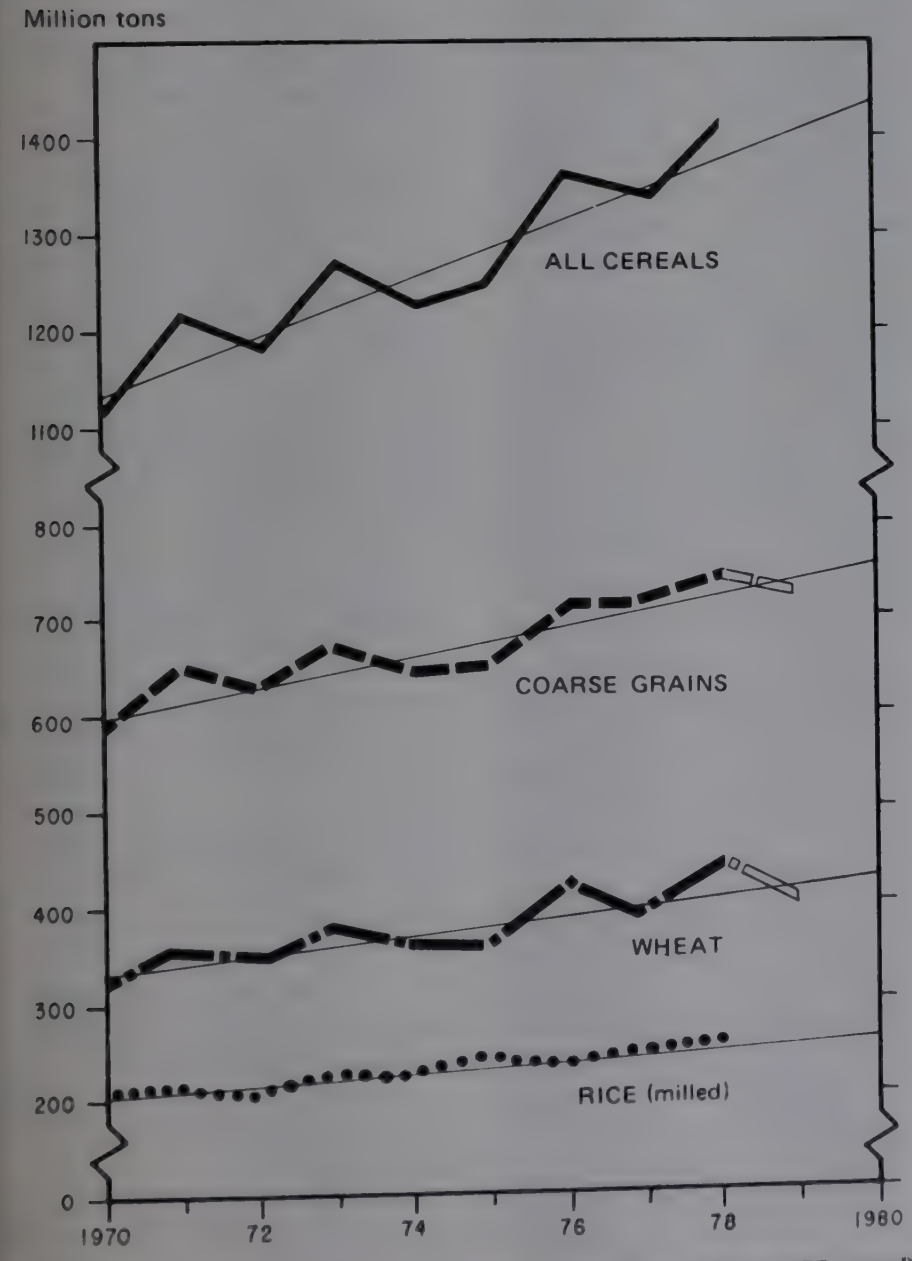

Figure 1. *World cereal production (actual and 1960-1977 trend)*
SOURCE: FOOD OUTLOOK, MAY 1979.

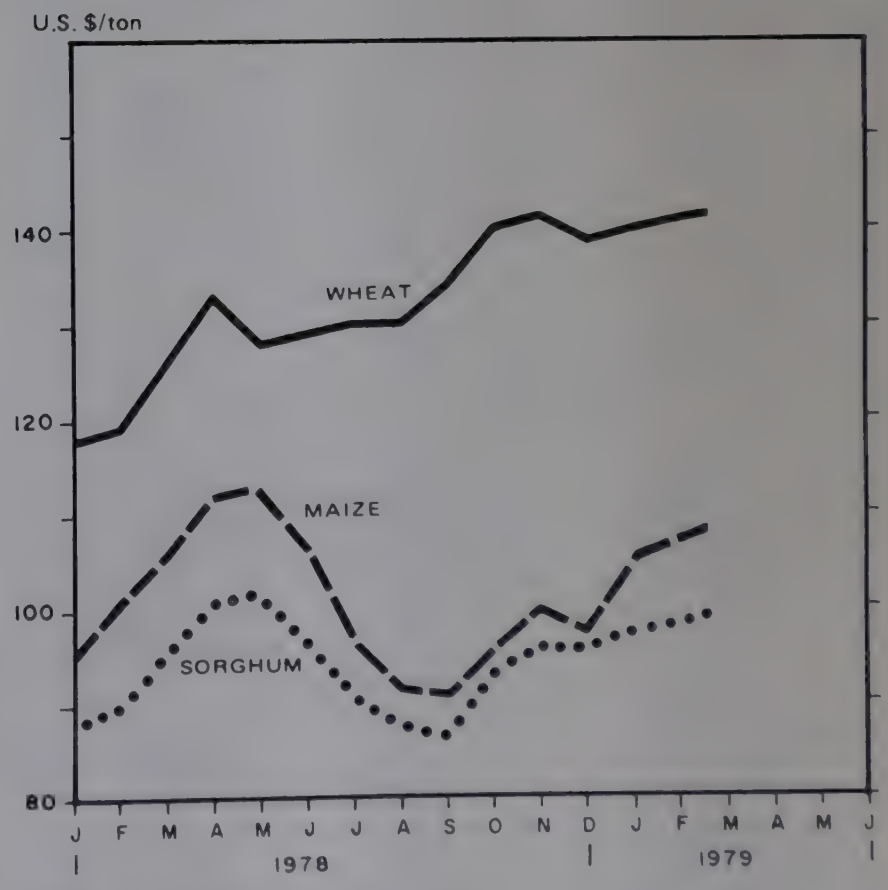

Figure 2. *Export prices (in US$)*
SOURCE: FOOD OUTLOOK, MAY 1979.

May 1979 indicates that the world's total grain production and coarse grain production for the 1979 calendar year would be 5 and 3.5 percent respectively below last year's record harvest (Table 1). At the forecast level (which is very tentative and subject to substantial revision) world wheat and coarse grain production would not be sufficient to meet consumption requirements in 1979/80, and carryover stocks would decline for the first time in five years.

Reflecting rising feed grain, feed protein and other feedstuffs prices, the composite feedstuffs price index in the world's largest feed market, the USA, was up in May 1979 by over 10 percent on the year before while the FAO vegetable oilcake and meal index also rose in terms of US dollars (Table 2).

Over the past year, the price of most livestock products, and particularly that of beef and veal, rose faster than the price of concentrate feeds in the majority of countries, with the notable exception of the European Economic Community and several centrally planned economies. As a result livestock/feed ratios, which show the number of kilogrammes of feed that a kilogramme of slaughter-weight livestock can buy, are still well above the 1971-78 average. However, while the US cattle/maize price ratio is still slowly rising, the usually sensitive US pig/maize price ratio has declined from the level reached a year ago, and has moved considerably below the historically high level reached in May 1977. ■

TABLE 1. **Wheat and coarse grains production - FAO forecast for 1979 as of 28 May 1979**
(Million tons)

Producer	Wheat			Coarse grains		
	1977	1978	1979 preliminary forecast	1977	1978	1979 preliminary forecast
World total	385.6	441.4	409	708.8	748.9	723
Developing countries	124.1	135.7	138	225.7	231.2	234
Developed countries	261.5	305.7	271	483.1	517.7	489
Africa	5.6	7.0	7	43.2	47.3	43
Latin America	11.5	14.8	14	58.9	55.9	58
North America	75.3	70.1	72	226.2	238.5	213
Far East	79.8	85.6	89	116.1	119.8	122
Near East	29.5	30.5	30	18.0	19.3	19
Eastern Europe	28.6	30.5	30	48.9	52.0	52
Western Europe	53.4	63.5	56	98.4	102.2	100
USSR	92.2	120.8	100	93.9	106.6	110
Oceania	9.7	18.6	11	5.2	7.3	6

Source: FAO Food Outlook, May 1979.

TABLE 2. **Selected market indicators**

Indicator	May 1979	May 1978	Change from previous year
US feedstuffs index	234	209	25
FAO vegetable oilcake and meal index	225	207	18
US pig/maize price ratio	19	21	—2

Sources: Feed Market News, California Department of Agriculture, and FAO Commodities and Trade Division

M.Sc. courses in animal health and veterinary public health

The Royal (Dick) School of Veterinary Studies, Edinburgh, United Kingdom, has recently issued prospectuses outlining M.Sc. courses in Animal Health and Veterinary Public Health.

M.Sc. in Animal Health

This course is intended for veterinarians interested in animal production and health. The successful graduate of this course should be well equipped to deal with future trends in disease patterns associated with current and new animal production systems.

The programme of study consists of course work in animal production and health, animal science and nutrition, animal behaviour and welfare, and studies in epidemiology, statistics and computing. A dissertation on independent work undertaken during the period of study has also to be submitted.

M.Sc. in Veterinary Public Health

The objects of this course are to provide academic achievement and practical competence in the field of veterinary public health.

The programme of study covers the zoonoses; public health administration and practice; environmental hygiene; epidemiology and statistics; inspection and hygiene of foods of animal origin, and food poisoning and residues and contaminants in foods. These courses are supplemented by practical work, particularly in relation to inspection and hygiene of foods of animal origin and food poisoning.

A dissertation on independent work undertaken during the period of studies has also to be submitted.

In both courses studies extend over one complete calendar year (October-September). Details regarding admission to either of these two courses may be obtained from the Senior Administrative Officer, Faculty of Veterinary Medicine, Royal School of Veterinary Studies, Summerhall Square, Edinburgh, United Kingdom.

Xth International Congress for Buiatrics, Mexico, D.F.

Following the invitation of the Mexican Association of Veterinarian Specialists in Cattle, the Tenth Congress of the World Association for Buiatrics was held from 16 to 19 August 1978, in Mexico City. Dr J. Avila García (President), Dr F. Hidalgo y Terán (Secretary) and Dr Aline S. de Aluja (Scientific Programme) were responsible for its preparation and organization. The President of Mexico, J. López Portillo, inaugurated the Congress. The majority of the 1 150 participants from 42 countries came from the Americas. The scientific programme contained nearly 200 items and was divided into six sections: reproduction; problems of dairy cattle production; mastitis; improvement of milk and beef production in the tropics; limiting factors and solutions; nutrition and miscellaneous.

Parallel sessions in four auditoriums were held with simultaneous interpretation in Spanish, French, English and

German. The unabridged congressional report is available from the Organizing Committee, Xth World Congress for Buiatrics, Ave. Morelos 20-707, México 1, D.F., Mexico.

As in the case of its predecessor this jubilee convention was notable not only for its important scientific and practical discussions but for the social gathering generously arranged by the host Government and much appreciated by the participants.

During the congress, new officers of the Sociedad Latinoamericana de Buiatría were elected. The Indian Society for Buiatrics (60 members), the Netherlands Groep Geneeskunde van het Rund (200 members) and the Israel Association for Buiatrics (90 members) were also admitteed as affiliated members of the World Association for Buiatrics. Membership now stands at 5 653. The composition of the executive assembly remained unchanged.

The next congress of the World Organization for Buiatrics, following the invitation of the Israel Association for Buiatrics, will be held in Israel in 1980; the ensuing congress will be held in 1982 in Amsterdam, the Netherlands, in response to the invitation of the Nederlandse Groep Geneeskunde van het Rund.

International Pig Veterinary Society - 1980 Congress

The above Congress is to be held in Copenhagen, Denmark, from 30 June to 3 July 1980.

The Congress is open for scientific contributions and papers on the aetiology, pathogenesis, clinical aspects, pathology, immunology, reproductive disorders, prevention and treatment of pig diseases and on management, feeding and housing in relation to disease prevention and the maintenance of health and fertility in pigs.

Information on the scientific programme and submission of papers may be obtained from: The 1980 IPVS Planning Committee, The Royal Veterinary and Agricultural University, DK-1870 Copenhagen V, Denmark, and on registration, accommodation and travel arrangements from: DIS Congress Service, 3 Knabrostraede, DK-1210 Copenhagen K. Denmark. A preregistration fee (due by 1 March 1980) of DKr 650 ($US135) has been estimated.

FAO/SIDA [1] international postgraduate courses in animal reproduction

Since 1954, a 9-month international postgraduate course in animal reproduction has been offered every other year in Stockholm, Sweden, under the sponsorship of the FAO/SIDA Cooperative Programme, to participants from developing countries. The number of participants per course is normally 15 and many countries in Africa, Asia, Latin America and the Near East have benefited from the training provided. The 13th animal reproduction course started in March 1979.

The purpose of the animal reproduction courses is to give participants postgraduate training in obstetrics, gynaecology, andrology, perinatal mortality, artificial insemination (AI) and the clinical and economic aspects of fertility and infertility. The training is primarily intended for veterinarians who are teachers or research workers in these fields or who are in charge of AI programmes and sexual animal health schemes in their own countries. The aim of the courses is to improve the standard of teaching and research and the training capacity of veterinary colleges, institutions and departments in the field of animal reproduction including artificial insemination. The impact of the courses will be in the multiplier effect of the participants' ability to train others and to develop research programmes of relevance to the developing countries.

The animal reproduction course comprises theoretical training in the form of lectures, seminars and discussions in the classroom, as well as practical training consisting of work in clinics (ambulatory and stationary), observers' theatre slaughterhouse, AI stations and the National Veterinary Institute. The participants also visit scientific institutes of interest to them in various parts of Sweden and in the neighbouring Nordic countries.

Social activities are also arranged by the course directors and the student union of the Swedish University of Agricultural Science to acquaint participants with Swedish customs and ways of life.

The course directors devote the intervening year between courses to follow-up activities. These include visits to previous participants as well as a regional seminar for the benefit of former participants in a particular region. The course directors also act as consultants and are frequently able to give advice and help in acquiring material necessary for progress in the work of previous participants.

Participants in the courses are selected from among candidates nominated by governments at the invitation of FAO. Admission requirements include a post-graduate degree and several years' experience. The courses are conducted in English.

Further information may be obtained from the Course Director at the following address: FAO/SIDA Animal Reproduction and AI Course, c/o SIDA, Fack, S-105 25 Stockholm, Sweden.

[1] SIDA = Swedish International Development Authority.

M.Sc. in tropical animal science

The School of Veterinary Medicine and Animal Production, University of Yucatan, Mexico, has recently announced the establishment of a postgraduate M.Sc. course in tropical animal science. The main emphasis of the course will be placed on research into the problems of the student's own country. Theoretical training will be provided by formal lectures but with a larger proportion of seminars and self-study under the guidance of supervisors.

The course is in three parts. The first part (September to December) is intended to provide the student with the theoretical basis necessary to understand any form of research and to assess the student's suitability for advanced training. The subjects taken in this part include digestion and metabolism, nutrition, production systems, statistics, and technical English or Spanish. The second part (December to September) is devoted to formal studies and to initiating research projects. The subjects taken in this part include biochemistry, physiology, genetics, microbioloy, statistics and technical English. In the third part (a further 6-12 months) the student concentrates on his research project while continuing his studies in fields related to his research and participating in seminars on particular topics.

Theses are always presented in July, 2 years after the commencement of the course.

The theoretical studies and much of the teaching is carried out by visiting specialists invited from various parts of the world.

The course is the responsibility of the University Department of Post-Graduate Studies which is strongly supported by the Mexican Government and a number of overseas governments.

Fluency in either Spanish or English is required and an ability to read and understand both languages is essential. Candidates must be science graduates, preferably with one year's professional experience in any field.

Respiratory diseases in cattle

Edited by W.B. MARTIN. The Hague/Boston/London. Martinius Nijhoff for the EEC. 1978. Current topics in veterinary medicine Vol. 3. 562 pages.

This book contains the record of a seminar held at the Moredun Institute, Edinburgh, from 8 to 10 November 1977, under the EEC Programme of Coordination of Research on Beef Production.

As a result of the progress made over the past 20 years in intensifying methods and systems of beef and dairy production on the farm and because of the movement of large numbers of cattle within and between countries of the EEC, there has been a corresponding increase in problems arising from respiratory diseases in cattle.

Formerly nonparasitic respiratory diseases received little attention but their growing significance and the complexity of the associated problems now facing veterinary authorities made the seminar from which this book has come, necessary to exchange information and ideas.

The book is an important contribution to modern veterinary literature. It covers a great deal of ground including: the incidence and epidemiology of respiratory diseases; parasitic diseases and diseases of adult cattle; the environment; virus diseases; and mycoplasmas and bacterial diseases. There are also chapters on pathology, therapy, immunity and vaccination, the application of research, and future developments.

Much valuable information is given on the aetiology, pathology, epidemiology, diagnosis, prevention and control of the diseases, and on conditions in EEC countries in a series of excellent presentations by leading research workers.

It is clear that relatively little has so far been complished and that many problems still remain unresolved. The main problem, as was pointed out by a speaker at the seminar in his closing remarks, lies in the fact that, after so many years, the aetiology of most of the respiratory conditions remain unresolved. If the course of a disease is not known or cannot be reproduced then it is very difficult to study it under controlled conditions.

However, as is clear from this book, much valuable work is being done; a number of important findings are recorded and new possible lines of approach are indicated. This book can therefore be of great help to all those interested in the health of beef and dairy cattle and their calves maintained under modern, intensive systems of production and management.

DEF

Manual of standardized methods for veterinary microbiology

Edited by Dr G.E. Cottral, Cornell University Press, Ithaca, NY. 1978. 709 pages. $US35.

This manual covers the clinical and pathological features of major infectious diseases of animals and describes the details of the procedures for the isolation and identification of the causative bacteria, viruses and fungi.

The manual is divided into four sections: general laboratory methods (80 pages); virology (240 pages); bacteriology (240 pages); and mycology (about 200 pages). Brief descriptions of techniques are included in the appendix (30 pages).

This manual consists of 67 chapters, and was developed by several governmental and scientific organizations in the United States. After 15 years of effort it was finally completed by the Plum Island Animal Disease Center, Greenport, Long Island, New York. The work of more than 100 authors was carefully edited by Dr Cottral.

This manual is useful for diagnostic work both in the field and in the veterinary laboratory. It provides the details of procedures for making a tentative field diagnosis and a final laboratory determination of the viral, bacterial and mycotic diseases of animals.

Y.O.

Textured protein products

By M.M. GUTCHO. Noyes Data Corporation, Park Ridge, N.J. 07656, United States. Food Technology Review No. 44. 1977. 355 pages. Price: $US 39.00.

This book is one of a series based on US patents issued since the early 1960s, and follows the series format: the chapters and some sections commence with a short description of the subject and the technical details of the patents follow, including some examples of processes and technical drawings. The titles and main content of the seven chapters into which the book is divided are as follows:

- Spun protein fibres: Boyer processes for the production of edible fibres; preparation of spinning dope; coagulation-bath modifications; methods for compressing and impregnating the tow of filaments.
- Protein fibres without spinning: use of heat exchanger at high pressure; extension into air; coagulation or precipitation of fibres.
- Expanded textured protein: techniques and methods of extension and expansion by applying various parameters, compounds and equipment.
- Protein texturizing techniques: conditions, factors, apparatus; use of various protein materials.
- Preparation of simulated meat products: meat analogues, simulated meats, binders for spun fibres, meat extenders.
- Other textured food products: meat-like texture from chewy protein gel; textured protein from yeast; wheat gluten-based meat-like products; restructured meat products; simulated nutmeats.
- Simulated flavouring agents for meat and meat-based products: meat flavour; poultry flavour; smoke flavour.

The separate indexes contain the names of companies to which the patents are assigned, the names of inventors and the numbers of the patents described in the book.

The book can be used as a source of technical information and also as a guide to US patent literature in the relatively new field of protein texturization technology and textured protein products.

S.C.

Modern poultry management in Australia

By W.J. NOWLAND. Published by Rigby Limited, 30 North Terrace, Kent Town, South Australia. 384 p. Price: $A39.95

This book is divided into 23 comprehensive chapters with

general references at the end of each. It covers the basic principles and all aspects of the modern poultry industry, with particular reference to Australia. In each chapter the author gives up-to-date information, primarily based on Australian experience. During the last 30-40 years Australia has developed poultry from a backyard industry to its fourth major primary industry. The publication provides information for both experienced poultry farmers and beginners. It is also useful for those working in the poultry industry, for veterinarians, advisers and students and others interested in poultry and poultry husbandry.

The following subjects are covered in simple language: egg production; broiler production; establishing a poultry farm; farm and game breeds; breeding; incubation; brooding; farm machines and mechanization techniques; replacement pullets; artificial lighting; egg quality and marketing; nutrition; diseases; and control and prevention. Many tables and statistics are presented, based on the most recent research findings in Australia and abroad, as well as the author's own wealth of experience as a leading adviser. Numerous clear photographs and diagrams are given. The reader can find useful information not only on the common farmyard hen, but also on turkeys, ducks, geese, squabs, guinea-fowls and pheasants.

T.V.

An introduction to animal husbandry in the tropics

By G. WILLIAMSON and W.J.A. PAYNE. Tropical Agriculture Series. Longman, London and New York. Third edition, 1978. 755 pages. Price: £10.95.

This is an expanded and updated version of the second edition of the book, which appeared in 1965. With G. Williamson retiring, the responsibility for this edition has been solely that of W.J.A. Payne, who has invited a number of scientists to contribute to the publication. In addition, three new chapters have been included, one on the *Llamoids* or *New World Camelidae,* the second on game as a source of meat and the third on wool production. Of these, two are by invited scientists. In all, seven of the sixteen chapters and one of the appendices are contributions by invited scientists. Although the latter have done a good job, the overall publication is rather uneven in quality. One would have liked to see more of a consistent development-orientation pervading the publication than a traditional text-book approach. The chapter on nutrition and feeding is a case in point. This chapter starts off very well by highlighting the fact that conventional animal feeds would inevitably become increasingly expensive due to the mounting pressure on world feed resources; however, it then gets lost in a consideration of the biological components of food and their evaluation, with the bulk of the chapter being devoted to types of forages, their management and conservation. Only a small section is devoted to other unconventional feeds, which have a much more important role to play in the future.

Be that as it may, the publication is suitable recommended reading for students, extension workers, administrators and livestock owners.

P.M.

Packaging, storage and distribution of processed milk

By W.B. TUSZYNSKI, FAO; edited by H.S. Hall. FAO Animal Production and Health Paper No. 11. 80 pages, with 18 tables and 52 figures.

This publication provides information on the technical requirements and their economic implications for seven major liquid milk processing and distribution systems. In planning a project that aims at introducing or extending a supply of inexpensive, safe, liquid milk, consideration must be given at an early stage to the optimum system for packaging, storage and distribution in the prevailing circumstances. There are many options, which can differ in cost by a factor of five, or even more. The choice of a system may therefore have a critical effect on demand, and hence on the success of the enterprise, and also may be fundamental in planning the processing plant and the distribution arrangements. This publication provides relevant information on the basic techno-economic implications of the principal systems at present applied successfully in many countries. It aims at helping to make wise decisions on the introduction of appropriate systems in developing countries.

The publication contains 10 chapters covering: the description of the systems; characteristics of packaging; specification of major equipment and layouts for packaging divisions of plants of different capacity; analysis of services requirements; estimates of labour requirements; models of transport systems; analysis of retailing costs; analysis of losses of packaging materials and milk; summary of costs; and analysis of matters that govern the choice of a system.

W.B.T.

The role of ruminants in support of man

Winrock International Livestock Research and Training Center, Petit Jean Mountain, Morrilton, Arkansas 72110, USA. April 1978. 136 p. Price: $US5.00

The Winrock International Livestock Research and Training Center was established in 1975 to assist in improving animal agricultural production systems to meet the challenge of a hungry world. This study is the result of its first major research effort. Nine papers commissioned from recognized scientists and two conferences organized by the Center contributed to the development of the major project document of this study.

The authors can be commended for their pragmatic approach. The first two chapters introduce the subject of ruminant production through a discussion of the relationship between ruminants and man and an overview of ruminant resources. The three chapters following analyse the key factors of production, namely, feeding, breeding and animal health.

Institutional and infrastructural constraints to production are then reviewed, and the study ends with considerations on future demand for ruminant products and on how to raise levels of production to meet this demand. The whole publication, which is supported by tables and graphs, gives a very informative account of the present and future role of ruminants.

FAO statistics for 1972 have been chosen as base-year data, although, as the authors point out, some major changes have occurred since then. [The FAO meat supply, demand and trade projections for 1985 for which the 1972-74 average has been applied, have recently become available (document ESC. PROI/78/2)]. However, any statistical differences are probably not of major importance as the study is a macro-economic analysis in which global figures serve the purpose of illustration and description.

The study represents a worthy inauguration of the Winrock International programme, and the hope is expressed in the preface that it will stimulate interest, action and further research. A logical development could be to single out some of the topics in the study for in-depth analysis. Considering that a major effort is needed to raise

output, attention might be given to items basic to production. In this context, an analysis of the significance of improved animal husbandry/management practices in the developing countries would be an important contribution; so also would a study of the economics of utilization of new feed resources and agro-industrial by-products.

E.L.

Animal wastes

Edited by E.P. TAIGANIDES. Applied Science Publishers, Ltd, London. 429 pages, numerous figures, tables, references and a glossary of terms. Price: $US50.00

This book is based on papers presented at the Seminar on Animal Wastes (SEMAW) held in Bratislava, Czechoslovakia, from 28 September to 5 October 1975. The Seminar was organized by the Regional Office for Europe of the World Health Organization and the Government of the Czechoslovak Socialist Republic in cooperation with the United Nations Development Programme.

The introductory chapters of the book deal with development and statistics relating to animal products inasmuch as they have a direct bearing on the expected magnitude and consequence of animal waste disposal. Under the heading, "The animal industry and the quality of the environment," the potential effects of intensive livestock production units are reviewed, with particular emphasis on health aspects. Criteria and guidelines for the selection of animal feedlot sites (as developed in Canada) are included, as are effluent regulations for animal feedlots in the USA. The report on noxious gases and odours shows the degree of specialization that is already developing in an attempt to solve this man-made problem.

Part II is concerned with technologies for the processing and treatment of animal wastes and their eventual disposal. It includes consideration of drying and composting. Part III emphasizes the utilization aspects of animal wastes. Energy production is analysed for the USA and existing re-feeding systems of animal wastes as practised or proposed in that country are reviewed. Liquid manure applications and economics are discussed in Part IV. Part V contains country reports from the German Democratic Republic, Romania, Poland, Hungary, USSR, Greece, the Netherlands, Bulgaria and Czechoslovakia. Of special interest is the establishment of manure banks in the Netherlands, which subsidize transport of liquid manure over long distances, thus stimulating its use on arable land not belonging to feedlot owners.

As a collection of papers from a single seminar, the coverage attempted is broad, but there is some unevenness in the depth to which the problem areas are treated, as well as in geographical coverage. Since most of the available literature on animal-waste disposal is restricted in subject matter and locale, this book is a welcome contribution to a possible broadening of knowledge at an international level.

W.H.B.

COMMENT

(Continued from front cover)

Governments will, therefore, need to evaluate their plans for the development of areas scheduled for control of tsetse, taking into account national development plans. For this purpose they are being urged to establish national trypanosomiasis committees and national tsetse and trypanosomiasis control units and to assess their needs in the training field.

In implementing plans for area development and tsetse and trypanosomiasis control under the Programme, FAO is fully conscious of the need to avoid taking any action that may have irreversible, adverse effects on the environment. In rendering advice to Governments it will continuously keep this fundamentally important principle in mind.

Trypanosomiasis and tsetse control methods have been greatly improved during the last 25 years and several of these have been applied effectively and economically. These include the use of trypanocidal drugs, vector control by ground and aerial spraying of insecticides, and selective removal of vegetation forming the habitat of the tsetse. In recent years growing interest has also been shown in the potential use of trypanotolerant livestock as a means of allowing more efficient land utilization in tsetse-infested areas. In addition, research is at present being carried out on the release of sterilized insects and the immunization of livestock.

A series of articles on African animal trypanosomiasis appeared in previous issues of this journal. These covered the disease and its chemotherapy (No. 7); chemophrophalaxis and the raising of trypanotolerant livestock (No. 8); control of vectors (No. 9) and economic problems (No. 10). In addition, the January/February 1979 issue of FAO's *CERES* contained an article on the subject under the title "After the tsetse". This issue of World Animal Review includes a major contribution to the literature on trypanotolerant cattle, attempting as it does to evaluate the current state of knowledge on some of the basic questions regarding trypanotolerance remaining to be answered. The state of progress made in regard to the immunization of livestock against the disease will be considered in a future issue.

Information for contributors

We welcome letters from writers suggesting ideas and subjects for articles.

Articles for the World Animal Review should normally be of a review or report nature and should be practical and informative. However, research results, when appropriately presented, may also be acceptable. Articles on the application of new ideas, work, equipment and methods will be particularly welcome, especially when they are of direct interest and of particular value to agricultural and animal scientists in developing countries.

Preparation of manuscripts

Manuscripts are accepted in English, French or Spanish. The Oxford English Dictionary is used as a standard for English spelling.

As far as possible the form and terminology used in articles should be straight forward and simple. Abbreviations or acronyms should be defined. Each article should be typed double-spaced on quarto paper (approximately 28 × 22 cm or 11.0 × 8.5 inches) on one side of the page leaving margins of 5 cm (2 inches). One or two levels of headings should be sufficient for most articles.

Length of manuscript

Articles should normally be 3 000-4 000 words in length, excluding tables and figures, with a maximum of 5 000 words for special articles. Important communications shorter than this are acceptable.

Tables, figures, graphs, photographs

These should each be on a separate page, numbered to correspond to their points of reference in the text, well spaced for printers' instructions to be inserted clearly, and with their sources identified. Graphs and diagrams should be clearly drawn in black Indian ink on thick, smooth white paper or on thin, smooth white board. Measurements should be in the metric system.

Negatives, photographs or slides are preferred but, where these cannot be supplied, photographs should be black-and-white, clear of full contrast and on glossy bromide paper.

Graphs, diagrams and photographs should be at least 13 × 18 cm (5.0 × 7.0 inches) and should be captioned on the back. Articles should normally be illustrated with four to six photographs and/or diagrams.

Please do not fold material. Send it suitably supported by cardboard in the envelope or package.

References and bibliography

The published work of other authors quoted in the text should normally be given a date in brackets after the author's name. This reference should be given in the list of references at the end of the article in the following order: author and initials; year, title of article/paper; title of journal; volume; part in brackets and page numbers. References should be in alphabetical order. Abbreviations of journal titles should, if possible, be those given in "The World List of Periodicals". References should be selected and normally restricted to 5-10 separate items. All references should be specifically referred to in the text.

The use of footnotes should be avoided as far as possible.

Republished articles

We prefer original articles but we do not rule out reprints, especially where these may give rise to the exchange of views and experience of development between animal production and health readers in developed and developing regions of the world.

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The decision of FAO is final on all matters regarding the editing and publication of articles. FAO cannot be bound to publish manuscripts. If an article is not accepted the author is free to publish elsewhere. Copyright and other proprietary rights with respect to manuscripts, with the exception of any material already subject to copyright or other proprietary rights, shall be vested in the author, who grants FAO licence to publish and reprint. The author must specify any material contained in the manuscript (including illustrations, diagrams and graphs) that is already subject to copyright or some other proprietary right, and must warrant that he has obtained authorization to use such material from the owner(s) or their legal representatives.

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Address for correspondence

Technical Editor, World Animal Production and Health Division, FAO, Via delle Terme di Caracalla, 00100 Rome, Italy.

Who are the readers?

FAO's World Animal Review is prepared in the Animal Production and Health Division and is directed primarily at assisting developing countries in their livestock industry. It is read by planners and technical and scientific staff in government departments, universities, research institutes, colleges, training centres, on projects and by extension officers in the field; by specialist and technical personnel of multilateral and bilateral agencies; by a considerable number of organizations and editors of professional and trade journals; and by scientists and individuals in developed and developing countries.

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